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REINFORCED THERMOPLASTICS FOR MAKING AN EXPANDABLE, RIGIDIZABLE WING TIP TANK

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Monsanto Research Corporation
Dayton, Ohio

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MONSANTO RESEARCH CORPORATION

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Air Force Materials Laboratory
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FOREWORD

This report was prepared by Monsanto Research Corporation, Dayton Laboratory, Dayton, Ohio, in conjunction with North American Rockwell Corporation, Columbus Division, Columbus, Ohio, under Air Force Contract AF 33(615)-67-C-1542 and was initiated under Project 7381 "Materials Evaluation" Task No. 738101 "Exploratory Design and Prototype Development". This work is administered under the direction of the Materials Support Division, Air Force Materials Laboratory and Fuels, Lubrication and Hazards Division, Air Force Aeropropulsion Laboratory, Wright-Patterson Air Force Base, Ohio with Mr. Edward J. Morrisey and Mr. Adam Cormier acting as Project Engineers.

This report covers work performed during the period March 1967 through December 1968 at Monsanto Research Corporation, Dayton Laboratory and North American Rockwell Corporation performed by C. J. North, D. L. Plessinger, J. L. Schwendeman, and I. O. Salyer. Mr. Salyer served as Project Manager and Mr. North served as Technical Director. North American Rockwell Corporation, Columbus Division, Columbus, Ohio, with Mr. Norik Ohanian as Project Engineer, was subcontractor to Monsanto Research Corporation.

The manuscript was released for publication by the authors in April 1969 as a Technical Report.

This technical report has been reviewed and is approved.

Albert Olevitch

Albert Olevitch
Chief, Materials Engineering Branch
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ABSTRACT

A program of work is described leading to the selection of a resin systems, reinforcement selection and fabrication methods for building a foldable deployable external wing tank for aircraft. Such a tank would be capable of being fabricated in its final configuration. After fabrication the tank could be folded, stored and shipped to the place of use At time of use the tank could be unfolded, inflated and cured in its final configuration.

The resin system and glass reinforcement selection was accomplished by screening over 150 potential resin systems and 6 possible reinforcement candidates. Twelve design concepts were screened. The selection of the final design was based on:

1. Weight saving potential.
2. High Nesting Ratio.
3. Stiffness and good load caring capability.
4. Ease of field erection.

A tooling concept was utilized that would allow the fuel tank to be fabricated over a removable mandrel. The mandrel shape is developed by placing a silicone rubber contoured bag in a female mold with an arbor clamped to the bag. The bag was pressurized against the mold and filled with ceramic (Veri-lite) nodules. After filling, a vacuum was applied to the bag and nodules to hold the bag in shape when the female mold is removed. After fabricating the tank, the vacuum is released and the nodules are removed.

A method for zone curing critical areas of the tank was developed. This would allow the tank to have specific areas cured and drilling and routing operations incorporated at the point of manufacture; and still allow the final curing of the tank in the field without further machining operations.

The objective of the program was successfully accomplished in that two tanks were fabricated by North American Rockwell. One of the tanks was folded and delivered to the Air Force for future deployment.

The second tank was fabricated folded, deployed and cured at North American Rockwell. This tank was intended for testing for strength and freedom from leaks.

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INTRODUCTION

SECTION I

INTRODUCTION

Much interest has been shown, in the past years, in foldable self-rigidizing structures by the Air Force and other services. Structures of various sizes and shapes are needed which can be deployed in earth or space environment.

Under Air Force Contract AF 33(615)-1484 Monsanto Research Corporation's Dayton Laboratory investigated the use of the seond order transition temperature of polymers as a pcssible means of providing a collapsible/expandable wing tank. This program is described in Technical Report AFML-TR-66-142- dated March 1966.

As a result of the work the Air Force awarded Contract AF 33-615-67C-1542 in July 1967 to Monsanto Research Corporation with North American Rockwell as a subcontractor. This new contract was for the fabrication of two full scale reinforced plastic external fuel tanks which could be expanded and rigidized in the field. The tank requirements were that the tank be collapsible with a 5-7 to 1 nesting ratio and meet the requirements set forth for those of the F-5A/B 150 gallon Northrop Corporation Norair Division External Wing Tank. This type of tank was designed to greatly simplify shipping and assembly problems in remote areas.

SECTION II

SUMMARY

SECTION II

SUMMARY

This report describes the work carried on by Monsanto Research Corporation, Dayton Laboratory, and North American Rockwell Corporation, Columbus Division under the direction of Wright-Patterson Air Force Base.

Prior to this contract, Monsanto developed a resin system that would change from rigid glass to flexible rubber. This change occurs when thermoplastic or lightly cross-linked polymers are heated to above their second-order transition. This was a reversible system and was demonstrated under contract AF 33(615)-1484 to be feasible in subscale wing tank models.

Further work indicated that this reversible resin system was impractical for use on high performance aircraft for one reason, i.e., minimum of 80% resin content is required to make the structure foldable. The 80% resin content would raise the 140 pound target weight to between 280 to 420 pounds. This weight increase is due to the low physical properties that are normal for high resin content laminates.

Another resin system had to be used. Over 150 new resin systems and 6 glass reinforcements were tested and evaluated. The resin system finally selected for use in the wing tank program is an epoxy plasticized polyvinyl butyral with a dicyandiamide (Dicy) epoxy curing agent. This system calls for 25% polyvinyl butyral and 75% epoxy resin. A patent disclosure has been filed on this system. A glass fabric, 181 style E-glass constructed from yarns designated as ECDE 75-1/o, was selected and impregnated with the resin system.

Physical property tests performed on the B-staged preimpregnated fabric and on the cured laminates. The test results on the B-staged fabric indicated that it was well within Monsanto's material specification. The cured laminates were shown to be slightly below the strength of conventional cured high grade epoxy glass laminates.

In order to achieve the general objective of this program, which is to fabricate two exploratory glass reinforced fuel tanks that meet the specification of Reference (1), twelve design concepts were evolved. In the analysis of these design concepts, primary considerations were given to attaining the highest possible nesting ratio, while maintaining structural integrity, maximum fuel capacity, minimum weight requirements, and affording ease of field erection. The twelve basic designs were reduced to two prime candidates: They were a full length, partial depth hardback, and a saddle door-type hardback. The selection of the final design concept was also based

on the collapsibility, workability and adhesion tests of certain test specimens designed for this specific purpose. The saddle-type hardback was finally selected.

Some of the physical properties data of the material from which the tanks were manufactured were supplied by Monsanto Research Corporation. However, in order to gain more insight into the properties of the material and its behavior under certain prescribed conditions for tooling and manufacturing purposes, several exploratory tests were carried out at the facilities of North American Rockwell Corporation. Also, since some of the phases of the tooling concepts were the first of their kind in this size, development required certain feasibility tests on some of the materials and processes used.

In the design of the final full scale tank, two factors were of primary importance: (1) trade-offs between the engineering, tooling and manufacturing efforts and (2) certain preferences of Air Force and Monsanto Research Corporation, as to the final configuration of the tank. It was also necessary to maintain the tank's structural integrity equivalent to that of the metal tank which not only is constructed from a material of higher strength but it also includes seven stiffening bulkheads in its design. In view of this fact, several stress analyses have been performed to determine the optimum trade-offs of structural integrity, tank weight and nesting ratio.

In the process of the design of the collapsible tank that concurred with the selected design concept, the application of an unusual method of curing was adopted at North American Rockwell Corporation. The method consists of curing the B-staged semi-final product with positive pressure (in comparison to the conventional vacuum bagging method). The above method is the first known application for such a large size object. The expandable elastic bag, designed to apply positive pressure to the tank, served a dual purpose of being the male mandrel tool for the fiber glass lay-up.

The project was aimed at exploratory development and feasibility determination of an expandable rigidizable external aircraft fuel tank. Consequently, the necessary tooling design and processes for fabrication were also, to a degree, exploratory. The entire tooling concept, tool design and fabrication was based on the fact that only two prototype tanks were required to be manufactured; therefore, all the tooling was "soft" or non-production type tooling. A special developed lay-up mandrel was used. The mandrel is made by using a contoured female mold with a pre-contoured silicone rubber bag placed inside the female mold. An arbor is then inserted into the bag and clamped in place. The bag is pressurized through the arbor and the female mold, bag and arbor are held in the vertical position and ceramic nodules are poured into bag then vibrated until the bag is

filled. A vacuum is then applied to the inside of the bag holding the nodules firmly in place. The female mold is then removed maintaining vacuum and an easily removable mandrel is ready for the tank lay-up.

During the progress of this program it became more apparent that a process for zone curing had to be developed. If this could be developed it would eliminate any trimming, machining and drilling of plastic parts in the field Eliminating sets of trim jigs, drill fixtures, etc., from the various field installations that would rigidize the tanks. This process was developed and presently has a patent disclosure filed

Also, in the very early stages of this program, it was ascertained that only the final female curing tool would be delivered to the Air Force. Consequently, this tool was built to withstand shipping. The remainder of the tools and, in some cases, their supports were constructed without consideration of any shipping and/or longevity.

Two prototype tanks were fabricated in this program. The second tank was fabricated, zone cured, folded, unfolded, and completely rigidized. It included all the structural component parts in final assembly, i.e., saddle-door hardback, end attachment cones and bulkheads in place. But no plumbing parts were included.

The first tank was zone-cured, B-staged and collapsed only. It also included the same finished components as the above tank. Only the saddle-door hardback was assembled in the later tank prior to shipping.

During the fabrication and curing of the second tank, the female mold failed. The failure occurred in the bulkheads that were used to stiffen the flanges of the split female mold thus causing the flanges to open as much as 3/4 of an inch. With this the silicone bag failed forcing air into the uncured tank laminate. The flanges of the female mold were probably too weak for the load and temperature experienced. The female mold was later shipped to the Air Force in this condition. Because of this mold failure the second tank was molded and cured with a part of the glass laminate extruded into the separated mold flange on both sides. Dimples or wrinkles were developed along the top half of the tank. Both forward and aft of the saddle door. All of these defects were repaired except for the air entrapment. The repair was made using a room temperature curing epoxy resin system with unknown number of plies. This repair procedure was not in accordance with that initially outlined by Monsanto Research Corporation.

In summary, the concept of fabricating external fuel tanks using this method was shown to be feasible and practical.

SECTION III

TECHNICAL DISCUSSION

SECTION III

TECHNICAL DISCUSSION

A. RESIN SYSTEM EVALUATION AND ZONE CURING

The objective of our resin system evaluation was to find a resin system that would meet the following physical requirements:

1. Allowing the tank to be foldable during manufacturing and storage.
2. Long time storage in environment up to 125°F and still curable.
3. The resin system would allow tank deployment in the field with the least amount of work.
4. Give high physical properties to keep the tank weight to a target of 140 lb.
5. If possible, have the ability to refold for additional storage.
6. Compatible with JP-4 jet fuel.

Two basic resin systems (reversible and irreversible) were evaluated. The reversible (thermoplastic) system uses less than stoichiometric amounts of curing agent with Shell's Epon 828 epoxy resin. In Table I, Tests 1 through 10, 115 and 116 were conducted on the reversible system. The reversible system was flexible at elevated temperatures, allowing the material to fold or unfold; at room temperature, the system became rigid.

The irreversible system is a combination of thermoplastic and thermosetting resins mixed to give a flexible B-staged epoxy resin system that gives a permanently rigid system when cured. The irreversible system consists of polyvinyl butyral or polyvinyl chloride plasticized with Shell's Epon 828, Monsanto's Santoset, Union Carbide's ERL-2256, ERL 4221 and F.M.C.'s diallyl phthalate (DAP) resins. These resins were screened in Table I.

During August 1967, the Air Force asked MRC to subject likely resin system candidates to constant 165°F aging environmental tests. This test, started on the 15th of August, involved 13 systems. Other systems that looked good were added to the test chamber, and eventually 33 different systems were being tested (see Table II).

The wing tank would be carrying JP-4 jet fuel. The best design would be achieved when no liner is required. Therefore, a test to determine if the resin systems in the cured stage were compatible with JP-4 fuel was initiated. On 9 August 1967, MRC started the JP-4 fuel test using 18 different resin systems. Specimens were cut, weighed and Barcol hardness tested before exposure for 15 days in JP-4 fuel. After the 15th day, the specimens were rechecked for weight and Barcol hardness, resulting in no significant change (see Table III).

A reinforcement screening test was run concurrently with the resin screening tests. The following glass cloths were tested:

1. 181-A1100 finish (J. P. Stevens & Co.)
2. 2P-183 Volan A finish (Coast Mfg. & Supply Co.)
3. 2P-184 Volan A finish (Coast Mfg. & Supply Co.)
4. 2P-495 Volan A finish (Coast Mfg. & Supply Co.)
5. KC-2208 Woven Roving (Coast Mfg. & Supply Co.)
6. 918 Volan A finish (J. P. Stevens & Co.)

The glass cloths were impregnated with resin system 46 (Table I). The physical properties show that the 181 glass fabric has the best physical properties. If the filament winding process was used, a minimum of 200,000 psi in tensile and 8.0 x 10^6 tensile modulus could be expected (see Table IV).

In August, a meeting between the Air Force and Monsanto Research Corporation was held at Wright-Patterson Air Force Base. The various resin systems and their effects on the program were discussed. It was noted that to achieve the highest physical properties, a low resin content and high glass reinforcement would be necessary. However, if the reversible system was used, approximately 80% resin content was required for it to be foldable. The smallest bend radius without delamination was only one inch. The irreversible system could fold on a zero radius without damaging the structure if 30 psi was used to compact the laminate during the final cure. The only apparent drawback to the irreversible system was its shelf life during storage. At this meeting a decision was made to drop the reversible thermoplastic resin systems calling for less than stoichiometric amounts of curing agent. This decision was made based on the high strength requirements needed to meet the 140 lb weight limit of the plastic wing tank. The high strength required dense low resin content composites which would not fold readily even with thermoplastic resins. In the irreversible systems, the densification is accomplished simultaneously with "deployment" of the tank in the mold.

In mid-September, a meeting to review NAR design concepts was held at Monsanto Research Corporation with the Air Force, NAR, and MRC attending. During this meeting, several other items were discussed, including the possibility of filament winding the tank with the irreversible resin system. MRC felt that this system held the key to successful completion of all of the program's target requirements.

We also discussed the use of a contoured rubber heating blanket that would control the outside contour during cure of the irreversible system using glass cloth reinforcement. The Air Force was concerned at the possibility of technical difficulties in this approach.

The next meeting with the Air Force was held during the last week of September at Wright-Patterson Air Force Base with MRC. This meeting was held to discuss the various approaches listed in Table V. It was decided that MRC would make a 24 inch nose section sample using the thermoplastic material with 30-40% resin content, an irreversible system and a hardback. The test items were to be built on an Air Force supplied pattern. These samples were used to determine if the system was capable of folding and deploying. MRC was also given a new environmental test to run in place of the 165°F constant temperature.

The new aging test was started on 5 October 1967 with a 24 hour temperature cycle including 16 hours at 85°F, 3 hours to go to 125°F, 2 hours at 125°F, and 3 hours to return to 85°F (see Table VI).

During September 1967, MRC developed sufficient data to write the materials specification for the control purchase of the preimpregnated glass fabric. This specification (MRC-MS-001) appears as Appendix I. The process specification (MRC-MP-001) was also written. This specification appears as Appendix II.

In October 1967 MRC received a low-temperature epoxy female mold from WPAFB. This mold was to represent the nose section of our F-5 wing tank. The mold was approximately 17 in. long by 15 in. wide by 6 in. higher in the aft end. The mold, being too small, could not be used for fabrication of nose sections. (At least 8 in. extra around the part was required for bleeder and vacuum bag sealing compound.) The mold was made with epoxy resin and "T" curing agent (which is only good for 200°F). The parts that MRC intended to build on this mold required a cure cycle of 4 hours at 300°F. Thus, a new high-temperature female epoxy mold had to be built

The Air Force-furnished female tool was used to fabricate a male B-11 plaster model mounted on a 3/4 in. thick plywood surface 30 in. x 40 in., extending the aft end of the Air Force mold approximately 12 in. aft. The plaster model was then used to make a new female epoxy mold (see Figure 1).

With the new plastic female mold, MRC fabricated a wing tank nose section hardback. The hardback was made of 8 ply, 183 Volan A fabric with Epon 828 epoxy resin and the full stoichiometric amount of Z curing agent. This layup was then vacuum bagged, and the excess resin and air were paddled out of the part.

The part and mold were then placed in the oven and cured. The hardback was removed from the mold, trimmed and drilled; it was designated SN-1 (see Figure 2).

The first thermoelastic system nose section was fabricated with 12 ply, 181 Volan A fabric with Epon 828 epoxy resin and 5/8 of the stoichiometric amount of Z curing agent. The part was then vacuum bagged, and the excess resin and air were paddled out of the part. In order to reach the highest physicals and maintain foldability, an attempt was made to hold the resin content to 30-40%. (In the past, we required approximately 80% resin to fold on a 1 in. radius.) The part and mold were then placed in an oven and cured. The thermoelastic system part was then removed from the mold, trimmed, and drilled. This part was designated SN-2 (see Figure 2 for SN-2).

The second thermoelastic system nose section was then fabricated using 12 ply 181 Volan A fabric with Epon 828 epoxy resin with 5/16 of the stoichiometric amount of Z and 5/16 of the stoichiometric amount of aniline curing agents. The part was then vacuum bagged, and the excess resin and air were paddled out of the part. An attempt was made to control the resin content from 30-40%. The part (still in the mold) was placed in an oven for curing. It was then removed from the mold, trimmed, drilled, and designated SN-3.

The next part was fabricated from B-staged preimpregnated 181 Volan A fabric. The resin system mix used was 37.22% by weight of Epon 828 epoxy resin, 1.11% dicyandiamide (DICY), 12.41% Butvar B-76, 0.37% Thermolite #31, 42.39% acetone, 6.0% dimethylformamide (DMF) and 0.5% deionized H_2O. A heat gun was used to bond and form the B-staged fabric in the female mold. The part was then vacuum bagged and placed in a preheated oven (180°F) for 20 minutes. The tool and part were then removed from the oven. The vacuum was maintained for 12 hours. The part was removed from the tool, trimmed, and drilled. This part was then designated SN-4.

A demonstration for the Air Force was held in mid-October 1967. SN-1 (hardback) was bolted to SN-2 (thermoplastic system) to form a section nose 12 in. in diameter (aft end) with a 1-1/2 in. flange about the center (see Figure 3). The assembly was then placed in an oven at 300°F for 30 minutes. The tank was removed and an attempt was made to fold the SN-2 part without delamination. After an extreme amount of force was applied, the section started to delaminate. The section was then placed in the oven for an additional 15 minutes and was folded (using great force); the section delaminated over approximately 85% of its surface (see Figure 4). SN-2 had a resin content ranging from 34-44%.

The hardback was removed from SN-2, and SN-3 was bolted in place on SN-1. After 30 minutes in the oven at 300°F, the assembly was removed, and an attempt was made to fold the part. With the application of less force than that used on SN-2, the part started to fold but still delaminated. Approximately 60% of the part was delaminated during the folding operation (see Figure 5). SN-3 had a resin content ranging from 32-38%.

The hardback was removed from SN-3 and SN-4 was bolted in place on SN-1. The part was then folded at room temperature with some delamination resulting. Deploying and returning the part to its original shape required very little effort (approximately 1/10 of that used during the attempt to fold SN-2 and SN-3). This part was then recycled (folded and unfolded). (see Figures 6 and 7).

A fourth experiment was performed taking a casting of the resin system used in SN-3. After 30 minutes at 300°F, the resin casting became extremely flexible, in fact even more flexible than the other thermoplastic systems castings.

At the completion of the demonstration, the Air Force gave Monsanto the go-ahead to purchase the preimpregnated fabric to be used to make four tank sections for test and enough material to fabricate three tanks. The irreversible system with 181 Volan A fabric was selected for the further work.

The Air Force-furnished mold and serial numbered parts 1, 2, 3 and 4 were given to the Air Force.

The program at that time was to use preimpregnated cloth gores for the tank fabrication.

In November 1967, MRC sent a representative to the Cordo Division of Ferro Corporation, Mobile, Alabama, to witness and supervise the preimpregnation of wing tank fabric. Cordo requested the following:

1. Change boxing size to 50-75 handling. (This was granted).

2. Change from deionized H_2O. (All MRC work was based on deionized H_2O and this could not be changed).

3. Change the resin solids from 51.11% to approximately 75%. Our work indicated that if we dropped 5% acetone content, we would have a thick gel that would not impregnate the fabric. (No change was granted).

4. They wanted to know if we wanted the prepreg packaged in moisture-proof bags. The answer was yes.

5. They wanted to know if a red 2-mil polyethylene separator film would be satisfactory. The answer was yes.

Cordo mixed two 55-gallon drums of resin mix. Two test runs were made to adjust wiper blade settings, chamber temperature, and velocity of fabric. Cordo ran a continuous run of over 650 yards, taking samples at the beginning of Roll No. 1 and at the end of each roll to run resin solids, resin flow, volatile content, and gel time. All tests showed the material to be within specifications (see Figure 9). Between Roll No. 1 and Roll No. 2, a roll of 28 years was scrapped because of glass fuzz caught on the wiping blade. Other problem areas included foaming of resin in resin bath during impregnating, and resin pickup from tower rolls. The foaming was stopped by circulating resin in resin bath. The resin pickup from tower rolls could not be stopped; therefore, there are small, localized spots of excess resin on one surface of the fabric. The Cordo certification of the material is shown in Figure 8, and the Cordo product roll log is shown in Figure 9.

Two basic approaches were taken to determine if zone-curing could be achieved. The first approach was to locate a preform between two caul plates. The caul plates and specimen were put in a preheated press with approximately 1/3 of the specimen under the heated platen of the press. A 1/4 inch copper tube was located over and under the caul plates next to the heated platen. The copper tube was crimped on the end, and 48 No. 55 (9.952 dia.) holes were drilled on half-inch spacing. Compressed air was passed through the tube to keep

the area not to be cured cool (see Figure 10). The part was cured for 3 hours at 325°F and 30 psi. The specimen was cut in half, with one piece 1/3 of this length cured and the other 2/3 uncured. Half of the specimen was placed between two caul plates and press-cured (see Figure 12).

A second approach was to vacuum bag a layup of 12 plies (MRC-MS-001) with a ply of nylon bleeder fabric and 4 plies of cotton bleeder over the layup. A 6" diameter heating duct 12" long was placed over the layup, and an infrared (250 watt) light was positioned approximately 13" above the layup. The light was turned on for 2 hours, with the temperature ranging from 145°C to 152°C (293°F to 305.6°F) (Figure 11). The specimen, as shown in Figure 13, has a black line representing the location of the 6" diameter duct around the cured spot.

The press-molded process gives a sharp, straight line break in the cured-uncured zone. The vacuum bag process shows a ragged edge around the cured-uncured zone and also indicates a possible bleed-out (low in resin content) of resin adjacent to the cured spot.

Flexural test specimens were molded and tested for any drop in physical properties in the cured-uncured zone after the part is completely cured. These specimens were made with the press molding process (see Table VII).

In December 1967, Monsanto Company developed a one-step process for fabricating a wing tank of honeycomb sandwich construction. The honeycomb was of Hexcel's aluminum honeycomb type Flex-core-5052-.0025-3.7 lb/cu ft density. The Flex-core will provide the flexibility needed to fold the uncured wing tank. However when the tank is fabricated, we will have to use zone-curing in conjunction with the honeycomb sandwich construction. The zone-curing will help to hold the honeycomb in place during folding and unfolding.

During our development of the one-step process, MRC fabricated two panels approximately 12" x 12" using flex-core honeycomb 1/4" thick with 6 plies of MRC-MS-001 prepreg fabric on each side of the honeycomb. The panels were zone-cured (using our press method) on each end, approximately 2" x 12" (see Figure 14).

Panel (serial number) SN# HS-1 was folded several times as shown in Figure 15. The inside skin separated from the honeycomb core, but when straightened out to its original flat shape the part tended to assume its original shape. The panel was then placed into a press for final cure (see Figure 16). It should be noted that all signs of wrinkles were removed and the panel appeared to have been cured all at one time.

B. MRC PHYSICAL PROPERTY TESTING

To assure uniform testing of the pre-impregnated fabric, we selected 15 yards from Roll No. 1, 4, 7, 10 and 13 or Cordo Roll No. 4342, 4345, 4348, 4351 and 4354. The thirteen rolls of prepreg were manufactured in consecutive order. Roll #1 (or Cordo Roll #4342) was the first made with the starting yard next to the paper core. This meant that we would be sampling between manufactured yards #36 and 50, 185 and 200, 335 and 350, 503 and 518, 652 and 667.

Four test panels 12 in. x 12 in. x 0.125 in. (12 ply) were made from each test roll sample. Particular care was taken to lay-up the panels to give each ply the same warp direction. Each panel was then molded for three (3) hours at 325° ± 10°F at 30 psi. The tests conducted on each roll of prepreg are shown in Table VIII. Three (3) test specimens would be checked in each of three warp directions 0°, 45° and 90°, i.e., nine (9) specimens from each test roll of fabric. Five (5) test rolls were to be tested bringing the total to forty-five (45) test specimens for each test. The layout of test panels for each test roll is shown in Figure 17. The test results are shown in Table IX.

Some additional physical property tests were conducted on samples with varying cure cycles. One group of samples was cured for 3 hours at 325°F and 30 psi (same cure as specimens made and tested in Table IX) plus a post-cure of 4 hours at 400°F (see Table X). These specimens appeared to be equal or less than those tested in Table IX. Another group of samples was cured for 1 hour at 250°F and 20 psi, and for 4 hours at 400°F and 30 psi (see Table XI). Tests indicated that this cure cycle is equal to or less than those used in Table IX.

C. DESIGN CONCEPTS

1. General Approach

In order to achieve the general objective of this program, several design concepts were evolved. In the analysis of these design concepts, primary consideration was given to attaining the highest possible nesting ratio, while maintaining structural integrity, maximum fuel capacity and minimum weight requirements.

2. Design Concepts and Configurations

A large number of design concepts typical to this type of program were screened from the feasibility standpoint and the remaining design concepts were grouped into three major categories, each having several configurations as follows:

a. Hardback Design Concept

(1) Full Length, Half Depth, Hardback
(2) Full Length, Partial Depth Hardback
(3) Partial Length, Partial Depth Hardback
(4) Partial Hardback, with Bottom Stiffener
(5) Saddle-Type Hardback with Bulkheads

b. Rigid Central Section Design Concept

(1) Bellowed Forward and Aft Sections
(2) Collapsed and Rolled Forward and Aft Sections
(3) Folded and Overlapped Forward and Aft Sections

c. Miscellaneous Design Concepts

(1) Longitudinal Stiffeners
(2) Hinged Partial Length Rigid Halves
(3) Hinged Full Length Rigid Halves
(4) Telescoping Forward and Aft Rigid Sections

In order to make a selection of the best two design concepts from the twelve different concepts presented above it was necessary to make trade-off studies from the weight, stiffness, nestability and field erection standpoint. All these design concepts with their respective cross-sections and/or end views are shown in Figure 18.

3. Discussion of Design Concepts

a. Hardback Design Concept

The a.(1) design concept is advantageous from the stiffness and load carrying capability viewpoint. The full length, half depth rigidized hardback provides ample support for a thin shell, and the load path is widely and uniformly distributed. This design concept cannot, however provide more than 2 to 1 nesting ratio and also has the undesirable feature of excessive weight of the hardback. If the depth of the hardback is reduced by moving the horizontal edges of the hardback above the centerline, (i.e., the subtending angle θ is less than 180°), design concept a.(2) results which, in addition to having the advantages of design concept a.(1), will have the improved nesting ratio of more than 2 to 1. With the process of design optimization in the reduction of subtending angle θ, the nesting ratio can be increased to 3-4 to 1.

The a.(3) design concept, i.e., Partial Length and Partial Depth Hardback offers more collapsible area, therefore higher nesting ratio. The smaller size of the hardback itself represents a reduction in weight. However, the weight advantage gained in the reduced hardback size is offset by the additional weight of the excessive shell thickness which is mandatory in this design concept (due to absence of bulkheads) to maintain structural stiffness.

Instead of increasing the shell thickness to achieve structural stiffness, a longitudinal stiffener can be introduced to serve the same purpose. This results in design concept a.(4), i.e., Partial Hardback with Bottom Stiffener, which has good load carrying capability, but due to incollapsibility of the stiffener, the nesting ratio is limited to 2 to 1.

The design concept a.(5), i.e., Saddle Type Hardback with Bulkheads is another way of maintaining structural integrity of the tank without increasing the shell thicknesses. With this particular design concept, it is possible to increase the nesting ratio by reducing the hardback size and increasing the collapsible area of the tank. The bulkheads provide a good load path of the rigidized hardback, at the same time reducing the effective length of the unsupported shell for buckling considerations. With intricate design, a nesting ratio of 5-6 to 1 can probably be achieved.

b. Rigid Central Section Design Concept

In the design concept b.(1), Bellowed Forward and Aft Sections, it is possible to attain 3-4 to 1 nesting ratio, depending on the size of the central rigidized shell. This design concept also provides a protective hard shell around the collapsible portion of the tank.

However, the multiple folds produced by bellowed type of collapsing create undesirable problems such as resin-rich and resin-poor areas, reduction of strength, aerodynamically unsmooth surfaces, etc., all of which take place during the final cure thus rendering this concept disadvantageous. In general, in collapsible fiber reinforced plastic structures the number of the folds should be kept to a minimum in order to avoid the undesirable complications aroused by the delaminations and the lateral interlaminar movement of the material.

The design concept b.(2) was intended to increase the nesting ratio by reducing the shell size and rolling the forward and aft sections to avoid the disadvantages of bellowing type folds. This concept was abandoned due to the resistance of the material to roll thereby creating excessive lateral interlaminar movement of the layers. A by product of the above design concept is the b.(3) design concept, where the forward and aft sections were overlapped over the central rigidized section to avoid folding delaminations in rolled concept. This design concept, while eliminating the disadvantages of design concepts b.(1) and b.(2) above, creates larger girth size of the tank in collapsed condition, thus jeopardizing the nesting ratio requirements.

In addition to the above two major categorized design concepts, several unrelated miscellaneous design concepts were developed (few of which are described below).

c. Miscellaneous Design Concepts

In the breakdown of the tank by components, the weight of the hardback and/or the rigidized central section in any one of the above design concepts constitutes the major percentage of the total weight of the tank. It was therefore deemed necessary to eliminate the hardback and/or the rigidized central section by supporting the entire tank with longitudinal stiffeners. These stiffeners are locally reinforced and interconnected at the top of tank in the suspension lugs area as shown in cross-section of design concept c.(1) in Figure 18. Although this design concept offers good load carrying capability and considerable weight reduction, its nesting ratio is compromised because the precured stiffeners prevent the effective collapsing of the tank.

With the introduction of mechanical hinges in the supporting section of the tank, it is conceivable to increase the nesting ratio of the tanks, due to lesser curvature of the rigid halves. This concept is presented in the cross-section of design concept c.(2), i.e., Hinged, Partial Length, Rigid Halves concept. The intricacy of design, the hinge sealing problems and reduced load carrying capability of the rigid section combined with the difficulties that might be encountered

in the field erection of this type of construction are the undesirable features of this concept. The structural stiffness and the load carrying capability can be increased by extending the rigid supporting section over the entire length of the tank as shown in c.(3) i.e., Hinged Full Length Rigid design concept. This slight improvement has the penalty of excessive weight of the supporting structure and the impracticality of having hinges at double curvature areas forward and aft of the central cylindrical section of the tank.

The c.(4) design concept i.e., Telescoping Forward and Aft Rigid Sections, has the advantage of having the entire tank cured in sections prior to shipping, thereby eliminating field curing difficulties. The only curing to be performed at the field is the curing of attachments and joints, which could be accomplished at room temperature. However, this design concept is not exactly within the scope and/or objectives of this contract and is included here only as a suggestion for future contracts and design feasibility.

4. Conclusions

From the above discussions, it is apparent that in general each and every design concept has certain advantages and disadvantages. It is also apparent that in the final analysis, the advantages outnumber the disadvantages of the hardback concepts. After a thorough evaluation of the hardback concepts by the WPAFB representatives, Monsanto Research Corporation, and North American Rockwell Corporation, from the weight, stiffness, nestability and ease of the field erection, the selection of the design was narrowed down to two concepts, design concept a.(2), Full Length, Partial Depth Hardback and design concept a.(5), Saddle-Type Hardback with Bulkheads. The selection of one of the above mentioned two design concepts was finalized by means of a series of tests of lay-ups, zone curings, collapsibility, and final rigidization. The results are presented in the next section.

D. EXPLORATORY TEST PHASE

1. General Discussion of Tests

The resin system evaluation, the zone curing, and the physical property tests of the material used in this program were conducted. The data were supplied by Monsanto Research Corporation, as described in sections A and B. To gain further insight into the properties of the material and its behavior under certain prescribed conditions for tooling and manufacturing purposes, several exploratory tests were carried out at North American Rockwell Corporation. Since some of the phases of the tooling concepts were the first of their kind, development required certain feasibility tests on some of the materials and processes used. Also, in order to evaluate the two best design concepts (selected in section C above) from the workability, adhesion and collapsibility standpoints, and thus be able to select a final design concept, several test specimens were manufactured and subjected to the above tests. These test specimens, simulating various portions of the tank, will be discussed in the following subsections.

2. Test Classifications

All the tests described in the above discussion are grouped and categorized under the following general classifications:

a. Tank Material Physical Property Tests

(1) Thermal Characteristics
(2) Compression Modulus and Ultimate Stress
(3) Bearing Strength and Maximum Stress
(4) Sandwich Compression Stress
(5) Compaction Rate

b. Tooling Material Physical Property Tests

(1) Granule Compaction Rate
(2) Thermal Characteristics of Female Tool Material
(3) Parting Agent Tests

c. Collapsibility Tests

(1) Cylindrical Test Specimen c.(1)
(2) Cylindrical Test Specimen c.(2)
(3) Conical Test Specimen c (3)
(4) Conical Test Specimen c.(4)
(5) Vacuum Burst Test of c.(1) and c.(2)

d. Assembly Tests

(1) Nose-Cone Bolting Ring Assembly
(2) Tail-Cone Bolting Ring Assembly
(3) Bulkhead Attachment and Bonding

3. Test Results

a. Tank Material Physical Property Tests

In order to determine the coefficient of thermal expansion and the decomposition temperature two specimens with dimensions 7/16" x 15/16" x 3" were prepared from the material used for the tank manufacture and subjected to the following tests:

Test 1 - Coefficient of Thermal Expansion, from Room Temperature to 350°F.

Test 2 - Decomposition Temperature

Four runs were made on specimen used in test 1, (R.T. to 350°F). Expansion was the same in all four runs indicating good reproducibility. These data are shown in Figure 19. Coefficient of Thermal Expansion (α) is calculated as follows:

$$\alpha_{(78°F - 350°F)} = \frac{0.10}{100(350-78)} = 3.6 \times 10^{-6}/°F$$

$$\alpha_{(26°C - 177°C)} = \frac{0.10}{100(177-26)} = 6.6 \times 10^{-6}/°C$$

It was also observed that the weight loss in these four cycles was only 0.069 grams on an original specimen weight of 37.247 grams.

Specimen #2 was used in test 2 and run to decomposition. The percent expansion through 350°F was identical to that of Specimen #1. Decomposition occurred at 545°F(285°C). The recommended temperature limit therefore is 500°F, which is far beyond the working temperatures for this contract. The weight loss on this specimen (originally weighing 37.044 grams) was observed to be 0.721 of one gram. The Coefficient of Thermal Expansion (α) can again be calculated from the data of this specimen shown in Figure 19.

$$\alpha_{(78°F - 545°F)} = \frac{0.17}{100(545-78)} = 3.6 \times 10^{-6}/°F$$

$$\alpha_{(26°C - 285°C)} = \frac{0.17}{100(285-26)} = 6.6 \times 10^{-6}/°C$$

Tests 1 and 2 were run on HARROP Automatic Recording Thermal Expansion Dilatometer.

The Compression Modulus and Ultimate Stress test, the Bearing Strength and Maximum Bearing Stress test and the Sandwich Compression tests were conducted primarily to study the hardback and the precured land area characteristics

For the Compression Modulus and Ultimate Stress, test specimens were prepared from 12" x 12" panels made from a laminate of 12 plies of tank material The specimens were machined and tested as per LP 406 Method 1021 of Reference (2). Two cure temperature and pressure combinations were used: 325°F with 30 psi pressure and 1-1/2 hours curing time; and, 425°F with 15 psi pressure and 1-1/2 hours curing time. Anticipating reduced cure pressure requirements (in case the prior combination resulted into complex tooling build up) which could be compensated by increased temperature, the second pressure and cure temperature combination was conducted. The results of the above tests are shown in Table XIII. It can be observed that the Compression Modulus is higher than those supplied in Section A and B above.

The test specimens for Bearing Strength were machined and tested as per LP 406 Method 1051 of Reference (2). The tank material was cured at 335°F using 12" x 12" laminate of 12 plies, under vacuum bag pressure. The results of 4% deformation of the hole and maximum stress sustained by the five specimens are shown in Table XIV of Appendix II.

The use of sandwich structure for the hardback and the bulkhead components necessitated two tests for study of the adhesion of the material to the sandwich core The first test, involving two test specimens concentrated on the area where the two 0.040 inch tank material skins were bonded to the sandwich core with EC2216 adhesive. The second test also involved two specimens with the same geometry, but no adhesive was used. The test results are as follows:

Specimen Number	Skin Thickness	Load lbs.	Stress psi	
1	2 x 0.040 in.	830	8,943	w/adhesive
2	2 x 0.040 in	1,400	14,956	
1	2 x 0.040 in	1,160	12,446	w/o adhesive
2	2 x 0.040 in	1,090	11,546	

Although the averages of the first and second tests are very close (11,949 psi and 11,996 psi, respectively), the consistency of the results of the second test data indicate that when using the tank material in a sandwich structure, no adhesive is necessary and the tank material has good adhering properties.

In order to establish the variables controlling the dimensional tolerances of male mandrel and final female curing tool, a tank material compaction rate test was performed as follows:

Test 1 was conducted with uncured material to establish average material thickness under hand weight in lay-up. A weighted dial indicator was used on one lamination as shown in Figure 22. To simulate hand pressure, a 1.8 pound weight was used over a circular area (1.875 in. diameter). This is equivalent to about 12 pounds pressure per average hand. The results of five specimens varied from 0.016 to 0.018 inches in thickness. Test 2 was conducted in a similar manner as Test 1 to establish the thickness of built-up laminate of 4, 8 and 14 plies. The averages of the results were 0.061, 0.119, and 0.208 inches of thickness for 4, 8, and 14 ply laminates, respectively. This indicates that the compaction rate increases with increased number of plies, because the average thickness of each ply in the above laminates was 0.0155, 0.0149, and 0.0148 inches, respectively.

Test 3 was performed to establish the thickness of a built-up laminate under vacuum pressure. The vacuum was applied after the lay-up of each two plies as shown in Figure 21(c). The results of 4, 8, and 14 ply laminates were 0.0515, 0.0995, and 0.1735 inches in thickness with individual ply thicknesses of 0.0129, 0.0129, and 0.0124 inches, respectively. The end product, i.e., the 14 ply laminate, was cured under vacuum 335°F, and a new set of thickness measurements indicated a variation of 0.172 to 0.176 inches on the entire area. In test 4, a total of 14 plies were laid-up and vacuum-bagged only once. The laminate was cured under the same conditions as test 3, and the results of the measurements had a variation of 0.187 to 0.194 inches. An intentional wrinkle was put in the bag material, as shown in Figure 21(d); however, no appreciable effects were noted. The comparison of the final results of tests 3 and 4 indicated beneficial effects of multiple vacuum-bagging on the overall laminate thickness.

b. Tooling Material Physical Property Tests

The under vacuum compaction rate of the "SCR Veri-Lite" granules used in the construction of male mandrel was part of the overall requirements for establishing the variables affecting the dimensional tolerances of the tools used in this program. A metal cylinder approximately 12" high and 22" in diameter was used as a preliminary tool in

...maintaining this rate. The inside of the cylinder was lined with vacuum bag material, sealed and filled with the above mentioned granules. The test set-up is shown in Figure 23. In filling the cylinder with granules, compaction was achieved by hand vibrating the entire assembly and then applying vacuum to the bag. The reduction in the overall dimensions was much less than expected. An accurate measurement indicated a reduction of 0.030 inches in the 22 inch diameter and almost no change in the height of the cylinder. This factor and the relatively inexpensive cost of the SCR Veri-Lite granules was conducive to the decision of manufacturing the male mandrel from this material.

In order to determine the coefficient of thermal expansion of the material from which the final curing female tool was to be manufactured, two specimens with the dimension of 3" x 3" x 1/2" were prepared from the following composite:

2 Plies of 2P122 Surface fabric (TREVARNO)
4 Plies of 2P146 0.015 Glass fabric (TREVARNO)
6 Plies of H21 Tricon 0.070 Glass fabric (WIMPHEIMER)
FR 47 Surface Preparation Resin
FR 41 Laminate Resin

These specimens were tested in HARROP Automatic Recording Thermal Expansion Dilatometer for the following three tests:

Test 1 - Coefficient of Thermal Expansion from, Room Temperature to 400°F in the x-direction

Test 2 - Coefficient of Thermal Expansion, from Room Temperature to 400°F in the y-direction

Test 3 - Deterioration Temperature

For tests 1 and 2, the percent expansion at 400°F (204°C) was measured in x-direction. The specimen was then rotated 90° and measured in the y-direction. The temperature then was increased for test 3. The first signs of deterioration appeared at 465°F. The results of all three tests are shown in Figure 20. The recommended top temperature limit for this material is 400°F.

The coefficient of Thermal Expansion (x) is calculated as follows:

For the x-direction:

$$\alpha_{(78°F-400°F)} = \frac{0.3}{100(400-78)} = 9.3 \times 10^{-6}/°F$$

$$\alpha_{(26°C-204°C)} = \frac{0.3}{100(204-26)} = 16.9 \times 10^{-6}/°C$$

For the y-direction:

$$\alpha_{(78°F-400°F)} = \frac{0.27}{100(400-78)} = 8.4 \times 10^{-6}/°F$$

$$\alpha_{(26°C-204°C)} = \frac{0.27}{100(204-26)} = 15.2 \times 10^{-6}/°C$$

As indicated by the curves of tests in the y-direction on Figure 20, there is an apparent phase change with an accompanying volume increase at approximately 300°F (165°C). This does not appear in the test curve for the x-direction and does not reflect a significant change.

Also, the weight losses and dimensional changes after two exposures at 400°F were nil.

Because of close tolerance dimensioning of the tank and final female curing tool and in order to avoid freezing the part in the tool, it was necessary to have one of the best mold releases or parting agents. Two major tests were conducted with emphasis on the materials used and the sequence of operations as follows:

In test 1, the tool surface was first cleaned thoroughly (with steel wool and solvents) of all excess resin build up. After applying lecithin to the entire surface, the tool was put in the oven for one (1) hour at 200°F. Excess lecithin was wiped from the surface after removing the tool from the oven. After repeating the above operation three times, three coates of Number 2130E Parting Agent was applied to the tool surface (allowing each coat to dry 1/2 hour) and then buffed. As a last step, fluorocarbon was applied without wiping.

In test 2, the tool surface was again cleaned of all foreign matter, coated with R671 agent, and placed in the oven at 300°F for 12 hours. After cooling down the tool, three coats of Traffic Wax Paste was applied to the tool surface. Each coat was allowed to dry for 1/2 hour and buffed prior to the application of the next coat. Finally fluorocarbon was applied without buffing.

Because the results of test 2 were far superior to those of test 1, the second method was adopted in manufacturing of the tanks.

c. Collapsibility Test

To demonstrate and evaluate the ability of the tank structure to collapse and expand with ease and to substantiate the advantages of previously selected design concepts, it was necessary to fabricate several test specimens representing critical sections of the tank and test these specimens early in the design phase of the program. These specimens were fabricated with dimensions within acceptable tolerance (± 1/4 in.) to the actual dimensions of the tank.

At the outset, it was intended to zone cure the precured areas by heating blankets and by applying the pressure through the autoclave. This method, however, was unsatisfactory due to uncontrolled and uneven application of heat and complicated electrical and vacuum hook-up. An earlier test specimen with all its complexity of wiring, etc., is shown in Figure 24. Consequently, the entire zone curing procedure was reversed, i e , it was decided to apply heat and pressure through the autoclave and cool the collapsible (uncured, B-staged) portion of the tank by means of water conduits. The tools and their fabrication for these test specimens and also for the bolting rings are described in Section F and shown in Figure 25 and Figure 28

A total of four specimens were fabricated, two for each of the design concepts selected in Section C, i e., one cylindrical and one conical test specimen [c.(1) and c.(3), respectively] for design concept a.(2) - Full Length, Partial Depth Hardback, and one cylindrical and one conical test specimen [c.(2) and c.(4), respectively] for design concept a.(5)-Saddle-type Hardback with Bulkheads. In the case of the later specimen, it was decided that, for the test phase above, the 45° inclines at each end of the hardback [See Figure 18, a.(5)] should be eliminated to simplify the fabrication of the test specimen. The inclines were made perpendicular to the edge of the hardback, similar to design concept a.(3) as shown in Figure 27.

The hardback sections of both cylindrical test specimens were fabricated from a sandwich structure consisting of two skins consisting of seven plies of tank material and 3/4 in. thick flexible aluminum alloy core. The design drawings for both cylindrical specimens with pertinent details are shown in Figures 26 and 27.

The first specimen tested, the cylindrical test specimen c.(2), represented the cylindrical section of the tank in the saddle-type design concept with the above mentioned deviation. Figure 30 represents the precured and assembled partial hardback. Figures 31 and 32 show the collapsible portion of the test specimen added to the above hardback, B-staged and collapsed in a multiple fold, indicating the feasibility of a good nesting ratio of this concept. Figure 33 shows the final product after the test specimen was expanded and rigidized by curing in 325°F temperature for three (3) hours

The second specimen to be tested was the conical test specimen c.(4) representing the aft conical section of the tank in the saddle-type design concept. In the final full scale tank design, the forward and aft conical sections of the tank were nested in a precured component used for the attachment of the nose and tail cones. These components or Bolting Rings were also simulated for the test specimens c (3) and c (4). The aft conical section was laid-up from seven plies of tank material in accordance with the design drawing of Figure 29.

The three conditions of this conical test specimen (collapsed after B-staging) expanded and final cured conditions are shown in Figures 34, 35, and 36, respectively. Both of the above specimens were cured under vacuum bag pressure (~14.7 psi) due to a malfunction in the autoclave, and the fact that the tests had to be witnessed by Monsanto Research Corporation and Wright-Patterson Air Force Base representatives who were present at that particular date.

Both of the following test specimens, i.e., cylindrical and conical test specimens [c.(1) and c.(3), respectively] representing the cylindrical and conical sections of the tank in the Full Length Partial Depth Hardback design concept were cured under 30 psi pressure, at 335°F for 3 hours.

The cylindrical tool and the vacuum bagged cylindrical test specimens can be seen in Figures 37 and 38, respectively. Figure 39 represents the B-staged and collapsed cylindrical specimen c.(1), and Figure 40 is the final product after expansion and rigidization. The conical test specimen tool and the cooling coils before and after curing of the upper portion of the specimen are shown in Figures 41 and 42. The collapsed specimen after B-staging, the expanded and final cured product are shown in Figures 43, 44, and 45, respectively.

The results of all four test specimens above, especially the cylincrical test specimens, were exceptionally good. In addition to demonstrating high nesting ratio, the tank material exhibited good workability and excellent joining and bonding properties.

The buckling stresses were the most critical because of negative design requirements. Therefore, the two cylindrical test specimens were subjected to a vacuum burst test to substantiate the shell thickness established in the stress analysis section of this report. Both ends of each cylinder were blocked and sealed as shown in the test set-up in Figure 46. The cylindrical test specimen c.(1) which was 34 inches high failed at -13.5 psi pressure, i.e., at 150% of design pressure. The cylindrical test specimens c.(3) which had a height of 28 inches did not fail in buckling or in joint separation at almost perfect vacuum. This represents a 160% level of design pressure. No pressure loss or leakage was observed in either of the two cylinders.

d. Assembly Tests

A review of final design and tool drawings indicates an opening at the forward and aft ends of the wet portion of the tank. These openings are designed for the removal of the male mandrel supporting shaft after tank lay-up and subsequent B-staging. To block and seal these openings, a precured component was designed to accept the

conical forward and aft sections of the tank. These components, (shown in Figures 47 and 48) termed Bolting Ring and Pan, in addition to sealing the tank ends also serve the dual purpose of bolting the nose cone and tail cone to the tank.

Except for their size, the assemblies for the nose and tail cones bolting rings and pans are identical. The ring and pan were bonded with AF-126-2 adhesive and cured in accordance with Process Specifications, Appendix V. This assembly was then bonded to the tank end by applying EC-2216 adhesive to the faying surfaces. Assembly tests, necessary to assure perfect bonding with no leakage, were conducted simultaneously with the conical test specimens of the collapsibility test in sub-section c. above. The precured bolting ring and pan, resubjected to heat in the process of curing the conical test specimens, exhibited some softening of those areas that did not have pressure applied to them. This softening is characteristic of most epoxy matrix materials. It is somewhat excessive, however, in the tank material.

Because of this softening of the tank material in the process of reheating, the bulkhead attachment tests were abandoned, and it was concluded that the tank material is not suitable for fabrication of precured components such as bulkheads, bolting rings, pans, and attachment angles. Since the material to be used for the fabrication of the above mentioned components was optional, it was decided to use 181E glass instead.

4. Conclusions

Based on the results of the above exploratory tests, expecially the collapsibility test in sub-section c., it was concluded that the design concept c.(5), i.e., Saddle Type Hardback with Bulkheads is by far the most advantageous design concept. These advantages are: 1) higher nesting ratio, presently 3-4 to 1 and possibly 7 to 1 with overall design optimization, 2) weight saving feature of the partial hardback compared to full length hardback, 3) stiffness and good load carrying capability with the introduction of bulkheads, and 4) ease of field erection and final curing.

E. FULL SCALE TANK DESIGN AND ANALYSIS

1. Discussion

In the preceding sections it was determined that the design concept a.(5), i.e., Saddle-Type Hardback with Bulkheads was the most suitable design concept for this development program. In addition to the advantages enumerated, the final design configuration was also dictated by 1) trade-offs in the engineering, tooling and manufacturing efforts and 2) certain preferences of Air Force and Monsanto Research Corporation.

At the outset, it was obvious that the number of precured bulkheads in a collapsible tank should be kept to a minimum in order not to jeopardize the nesting ratio or affect the simplicity of field erection. The shell thicknesses of the tank tend to increase as the number of bulkheads are reduced thus increasing the weight of the structural integrity equivalent to that of the metal tank which not only is constructed of higher strength material but also has seven stiffening bulkheads. Several stress analyses, therefore, have been performed to determine the optimum trade-offs of structural integrity, tank weight, and nesting ratio.

While designing the collapsible tank, a new and unique method of curing was adopted at the North American Rockwell Corporation. The method which has been in the laboratory stage for the last few years, consists of curing the B-staged semi-final product with positive pressure (as opposed to the conventional vacuum bagging method). The above method is the first known industrial application for such a full scale component. The expandable elastic bag, designed to apply positive pressure to the tank, served the dual purpose of being the male mandrel tool for the fiber glass lay-up. For this reason, the details of the bag development are discussed in the tooling section of this report.

2. Design Considerations

The factors affecting the full scale collapsible tank design were influenced by several independent and major components of the tank including:

a. Physical size of the hardback
b. End cone attachments
c. Internal plumbing of the tank
d. Access hole for repairs

Each one of these design factors is discussed in the following subsections. The design drawings and details are included as Figures 49 through 57 inclusive, in Appendix I.

a. Physical Size of the Hardback

In a preliminary stress-analysis (later substantiated), it was indicated that the use of two bulkheads was sufficient for the strength requirements of the collapsible tank after rigidization. In addition to locating these two bulkheads somewhat equidistant from the center of gravity of the tank, it was desirable to limit their extent to the cylindrical portion of the tank, i.e., Stations 66.0 to 100.0, for uniformity of design, tooling and manufacture. It was also desirable to encompass these bulkheads with the widest possible section of the hardback to create better load carrying capability. Also the subtending angle θ was kept at 180° to facilitate the assembly of the bulkheads. As a result, the widest section of the hardback had to be at least 30 inches long and semi-cylindrical. The two ends of the hardback were beveled upward toward the upper mold line of the tank, thus making the longest dimension of the hardback about 60 inches.

Initially the hardback was to be bonded to the collapsible portion of the tank. Accessibility requirements dictated that the hardback be bolted instead.

b. End Cone Attachments

One of the factors affecting the design of the final configuration of the tank was the problem of attaching the nose cone and the tail cone and fins to the tank wet area (see Figure 62). To avoid the complications of sealing for fuel leakage, it was decided that the end cones would be bolted to precured parts, termed Bolting Ring and Pan, and then would be bonded to the main body of the tank. Allowances were made by stepping both the design and tooling of the tank to accept the Bolting Ring and Pan assembly while maintaining the aerodynamically smooth surface of the tank.

c. Internal Plumbing of the Tank

Initially, the Northrop Corporation F-5 metal wing tank was to be cannibalized, and certain components including the internal plumbing in the collapsible tank was to be used Instead, a Sergeant Fletcher tank with different mold line data, plumbing layout and dimensioning was delivered to North American Rockwell Corporation by the Air Force. Since, at the time of delivery of the new metal tank, the design of the collapsible tank was well advanced in accordance with the F-5 tank data, the use of the internal plumbing in the collapsible tank was abandoned due to dimensional and layout mismatch. However, this situation did not eliminate the potential use of gas cap, vent

line and fuel line nipples, suspension lugs and sway brace contact points in the design of the outer skin of the collapsible tank. This necessitated making special provisions for local stiffness in the hardback area for some of the above mentioned fittings and extending the length of the hardback to include all the fittings.

d. Access Hole for Repairs

Although the actual installation of plumbing was eliminated, it was still necessary (for realistic simulation) to have an access hole for plumbing repairs in the upper central portion of the tank. The diameter of the access hole in the metal tank was in the vicinity of 8 inches. The Air Force, however, preferred to have an access hole of at least 18 inches in diameter. The size of this access hole and the fact that there were no provisions made for having bulkheads immediately adjacent to it endangered the load carrying capability of the hardback. Finally, it was decided to eliminate the access hole altogether and make the entire hardback removable in order to gain access to the interior of the tank for repairs.

There are two advantages associated with the above change. First, the bulkheads can be permanently installed in the tank, by bonding, after the collapsible portion of the tank is rigidized. Secondly, more bulkhead to tank skin contact area can be achieved with the possibility of lowering the bulkheads into the tank parallel to the longitudinal axis of the tank and then rotating them 90 degrees in the transverse direction.

3. Stress Analysis

This program required performing a stress analysis using standard handbook equations that do not include the effects of dynamic loading, creep, fatigue and/or temperature. For this static stress analysis, Equations 1 and 3 have been used extensively.

The envelopes of Maximum Shear V_R, Twisting Moment M_X, and Bending Moment M_B obtained from Equation 1 are reproduced in Figure 60. The two shell buckling parameters used in this analysis are obtained from Equation 3 and reproduced in Figures 58 and 59.

Three different types of analyses were performed as follows:

a. Preliminary Analysis for Tentative Shell Thickness
b. Configuration Trade-off Studies
c. Final Stress Analysis

The latter two analyses are basically similar except for the unsupported effective length between the stiffeners and/or bulkheads.

a. Preliminary Analysis for Tentative Shell Thickness

A non-dimensional analysis has been performed at the most critical section of the tank to arrive at a tentative shell thickness of the fiber glass tank as a starting point to account for changes in the modulus of elasticity (E), effective cylinder length (L) using the margin of safety equations (Equation 1) below.

$$M.S. = \frac{2}{R_P + R_B + \sqrt{(R_P + R_B)^2 + 4(R_S + R_{ST})^2}} - 1 \qquad (1)$$

The ratios of compressive stress due to external pressure (R_P), compressive stress due to bending (R_B), shear stress due to transverse shear (R_S) and shear stress due to torsional shear (R_{ST}) are proportional to E, t, and L in the following manner.

$$\left.\begin{array}{ll} R_P \sim \dfrac{L^2}{Et^3}, & R_S \sim \dfrac{L^2}{Et^3}, \\[2ex] R_B \sim \dfrac{1}{Et^2}, & R_{ST} \sim \dfrac{L^2}{Et^3}, \end{array}\right] \qquad (2)$$

Letting the subscript zero denote the properties of the original metal tank, the non-dimensional values of the above ratios become

$$\left.\begin{array}{ll} R_P = A_P\left(\dfrac{t_0}{t}\right)^3\left(\dfrac{L}{L_0}\right)^2\left(\dfrac{E_0}{E}\right) & R_S = A_S\left(\dfrac{t_0}{t}\right)^3\left(\dfrac{L}{L_0}\right)^2\left(\dfrac{E_0}{E}\right) \\[2ex] R_B = A_B\left(\dfrac{t_0}{t}\right)^2\left(\dfrac{E_0}{E}\right) & R_{ST} = A_{ST}\left(\dfrac{t_0}{t}\right)^3\left(\dfrac{L}{L_0}\right)^2\left(\dfrac{E_0}{E}\right) \end{array}\right] \qquad (3)$$

where A_B, A_P, A_S and A_{ST} are non-dimensional constants for their respective ratios of Equation 1 and are used for iteration purposes only.

Substituting these values in Equation 1 and factoring out the predominant elements the following non-dimensional equation results:

$$M.S. = \frac{2\left(\dfrac{t}{t_0}\right)^3\left(\dfrac{L_0}{L}\right)^2\left(\dfrac{E}{E_0}\right)}{A_P + A_B\left(\dfrac{L_0}{L}\right)\left(\dfrac{t}{t_0}\right) + \sqrt{\left[A_P + A_B\left(\dfrac{L_0}{L}\right)\left(\dfrac{t}{t_0}\right)\right]^2 + 4\left(A_S + A_{ST}\right)^2}} - 1 \qquad (4)$$

Due to the presence of t and L in A_B of the denominator, it seems that an iterative solution is imminent. However, since the effect of A_B is much smaller than the rest of the ratios the solution can be obtained in one or possibly two iterations.

The original metal tank has a bulkhead frame spacing of approximately 20 inches. If no bulkhead frames are used in the fiberglass tank and an effective length of 140 inches is used, then

$$\frac{L_0}{L} = \frac{140}{20} = 7$$

and since the value of $\left(\frac{t}{t_0}\right)^3\left(\frac{L_0}{L}\right)^2\left(\frac{E}{E_0}\right)$ must equal one to maintain the original safety margin, then;

$$\left(\frac{t}{t_0}\right) = \sqrt[3]{\left(\frac{L_0}{L}\right)^2\left(\frac{E}{E_0}\right)}$$

Using the compression modulus of elasticity of the tank material as 2.457×10^6 psi in the above equation, we will have

$$\frac{t}{t_0} = \sqrt[3]{49}\ \sqrt[3]{\frac{10 \times 10^6}{2.457 \times 10^6}}$$

the maximum t_0 used in the metal tank is 0.071 in. therefore

$$t = (5.8425)\ (0.071) = 0.415 \text{ in.}$$

This thickness which is equivalent to some 40 plies of tank material obviously is intolerable and the effective length should be reduced.

One way of reducing this effective length is to account for the stiffness contribution of the conical ends. This results in an effective length of 100 inches which gives the new thickness of:

$$t = \left[\sqrt[3]{\left(\frac{100}{140}\right)^2}\right] (0.415) = 0.331 \text{ in.}$$

It should be noted that both the above thicknesses are prior to iterations in equation (4), and can be reduced by further iteration. However, an inspection of equation (4) will indicate that these thicknesses can not be reduced by more than 20%, therefore a configuration better than the unstiffened shell seems necessary.

b. Configuration Trade-off Studies

Since both the above thicknesses will result into excessive weights for the tank shell, the effective length L should further be reduced. The best method of reducing this effective length without jeopardizing the shell buckling characteristics is the use of bulkhead frames. If the same number of bulkhead frames are used in the fiberglass tank as were used in the aluminum tank, i.e., $\frac{L_0}{L} = 1$ then;

$$t = \sqrt[3]{\frac{E_0}{E}}\, t_0 = (1.597)\,(0.071) = 0.113 \text{ in.}$$

which directly accounts for the difference in the moduli of elasticity.

With the usage of bulkhead frames the M.S. calculations, specifically the ratio of R_P, should be based on a short cylinder assumption, hence the new ratio of compressive stress due to external pressure is proportional to E, t, and L as follows:

$$R_P \sim \frac{1}{Et^2} = A_P\left(\frac{t_0}{t}\right)^2\left(\frac{E_0}{E}\right) \qquad (5)$$

which, if substituted in Equation (1) with the rest of the ratios of equation (3), will yield:

$$M.S. = \frac{2\left(\frac{t}{t_0}\right)^2\left(\frac{E}{E_0}\right)}{A_P + A_B + \sqrt{\left(A_P + A_B\right)^2 + 4\left[\left(A_S + A_{ST}\right)\left(\frac{L}{L_0}\right)\left(\frac{t_0}{t}\right)\right]^2}} - 1 \qquad (6)$$

The solution of this equation is also an iterative one due to the presence of L and t in the demoninator, and the initial value of t can be obtained as follows:

$$\left(\frac{t}{t_0}\right)^2\left(\frac{E}{E_0}\right) = 1$$

$$t = \sqrt[2]{\frac{E_0}{E}}\; t_0 = \sqrt[2]{\frac{10 \times 10^6}{2.457 \times 10^6}}\,(.071) = 0.143 \text{ in.}$$

A relatively small shell buckling program has been prepared on a digital desk computer (RECOM II), and, using the above thicknesses as a starting point, several runs have been made to arrive at the minimum thicknesses to determine the smallest possible positive margin of safety. The results of the final runs are shown in Table XIX.

The equations and graphs used for these calculations are obtained from Reference 2 and are as follows:

$$F_{P_{CR}} = \frac{k_p \pi^2 E}{12(1-\nu_e^2)}\left(\frac{t}{L}\right)^2 , \qquad F_{ST_{CR}} = \frac{k_t \pi^2 E}{12(1-\nu_e^2)}\left(\frac{t}{L}\right)^2$$

$$F_{B_{CR}} = .42E\,\frac{t}{R} , \qquad F_{S_{CR}} = 1.6\,F_{ST_{CR}} \tag{7}$$

$$f_P = \frac{pR}{t} , \qquad f_{ST} = \frac{M_x}{2\pi R^2 t}$$

$$f_B = \frac{M_B}{\pi R^2 t} , \qquad f_S = \frac{V_R}{\pi R t} \tag{8}$$

whence the stress ratios become:

$$R_P = \frac{f_P}{F_{P_{CR}}} , \qquad R_{ST} = \frac{f_{ST}}{F_{ST_{CR}}}$$

$$R_B = \frac{f_B}{F_{B_{CR}}} , \qquad R_S = \frac{f_S}{F_{S_{CR}}} \tag{9}$$

c. Final Stress Analysis

From the analyses performed in subsections a. and b. above and from the comparison of stress ratios and margins of safety in Tables XVII and XVIII, (specifically the data concerning R_P, (the buckling stress ratio due to hydrostatic pressure), it is evident that the major contributory

factor in the buckling stresses of the tank shell and consequently the bulkhead frame spacing is the negative tank pressure. It was suggested by the Air Force that a comparative stress and weight analysis based on the following two loading cases be conducted:

CASE I	CASE II
-2 psi working pressure	-3 psi working pressure
-4 psi proof pressure	-6 psi proof pressure
-6 psi collapse pressure	-9 psi collapse pressure

A total of 24 optimization analyses were performed with the above pressure combinations using factors of safety of 1.25 and 1.50 (suggested by Air Force) both on a tank with bulkhead frames at 34 inches and on a tank without bulkheads. The weight calculations were based on the summation of computed weights of frustums, 5 inches high, i.e., at every 5 inch station, using average thicknesses and average radii as shown in the equations of Figure 63.

The results of proof pressures only, i.e., 4 psi and 6 psi, are shown in Table XV. Based on the data from the above mentioned analysis, the Air Force and Monsanto Research Corporation representatives selected the following configuration for final analysis:

Case I Loading;	-2 psi working pressure -4 psi proof pressure -6 psi collapse pressure
Factor of Safety;	F.S. 1.50
Bulkhead Spacing;	34 inches
Anticipated Tank Weight;	149.25 pounds
Young's Modulus;	$E = 2.547 \times 10^6$ psi
Poisson's Ratio;	$\nu_\epsilon = 0.14$

A final stress analysis of the tank shell has been performed using the above data, and the results are recorded in Table XIX. Due to symmetry, only one half of the tank is analyzed and the values duplicated for the other half. In this table Column 1, 2, and 3 represent the tank stations, tank radii at these stations, and the thicknesses used, respectively. If the thicknesses in Column 3 are multiplied by a factor of 100, the resulting integer indicates the approximate number of plies used at each station. Column 4 is obtained by multiplication of Columns 2 and 3 and the results are used to obtain the "length-range parameter" Z_L of Column 5. Using this

parameter, the buckling coefficient of hydrostatic pressure k_p and the buckling coefficient for cylinder in torsion k_t are obtained from Figures 58 and 59 and recorded in Columns 6 and 7. Using the above coefficients, the allowable compressive stress due to hydrostatic pressure, $F_{P_{CR}}$, the allowable shear stress due to torsional shear $F_{ST_{CR}}$, the allowable shear stress due to transverse shear $F_{S_{CR}}$, and the allowable compressive stress due to bending $F_{B_{CR}}$ of Columns 8, 9, 10 and 11 are obtained, respectively. Columns 12, 13, and 14 represent the bending moment, the twisting moment and the transverse shear loadings on the tank structure, respectively, which were also obtained from Equation 1.

The actual calculated stresses of the tank are shown in Columns 15, 16, 17, and 18 which represent the stresses due to hydrostatic pressure, twisting moment, transverse shear and bending moment, respectively. The ratios of these actual stresses to allowable stresses is represented by symbol R (R_p being the ratio of f_p to $F_{P_{CR}}$, etc.) which are recorded in Columns 21 through 22. Using an orthogonal combination of these ratios, i.e., the same equation that has been used for the design of the metal tank, the margins of safety for each station has been obtained as shown in Column 23.

The numerical calculations of all the above analyses are tabulated in Tables XVI, XVII, XVIII and XIX, and the description of Columns 1 through 23 for the later table in paragraph above is applicable to all four tables.

4. Flat Pattern Gore Development

Unlike the metal tank, the plastic tank makes it possible and advantageous to have variable thicknesses throughout the length of the tank. The metal tank was designed for two levels of maximum loads, one for the cylindrical and the other for the conical sections; hence two uniform thicknesses of sheet metal were used for the construction of the tank shell. This uniformity of thickness in sheet metal cannot be avoided. However, through an optimization technique in the design of laminated fiberglass structure, it is possible to drop off laminates to conform with stress diagrams and still satisfy the load carrying requirements.

As can be seen from the final stress analysis (Column 3 of Table XIX), the shell thicknesses have been dropped off at various stations from a starting thickness of 14 plies at the cylindrical center of the tank. The tank shell, therefore, consists of several concentric and conical frustums, which if developed, form the flat pattern gores shown in Figure 64. Another advantage of having precut and preformed gores is the fact that no wrinkling of material takes place in the lay-up due to reduction of radii in the conical ends of the tank.

A small digital computer program was prepared to generate the information needed for detailing and drawing the gores. In order to avoid bulging in the thicknesses throughout the length of the tank, the overlaps have been distributed as evenly as possible. In the conical portions of the tank, the width of the gores has been limited to about 15 inches or under to eliminate the effect of excessive wrinkling in the lay-up process.

The overlaps in the longitudinal direction have been influenced by two factors: 1) no two overlaps should occur at any one station and 2) each overlap should be imbedded between two solid laminae. The overlaps in the circumferential direction are controlled only by a minimum space of 2-3/8 inches in the cylindrical section and a minimum space of 1-11/16 inches in the conical sections of the tank. By following an almost symmetrical pattern of the longitudinal overlaps, it was possible to create several symmetrical and identical gores and reduce the number of the templates required to produce all the gores. These parts are identified with connected arrow lines in Figure 92.

F. TOOLING

1. Discussion

The use of Northrop Corporation's F-5 metal wing tank as lay-up male mandrel and the possibility of adding one or two other tools was contemplated. However, as the design concepts, exploratory testings, and the final design configuration evolved through numerous trade-off studies and other design considerations, the tooling concepts and tool design parameters also went through a similar evolution, discarding all the previously conceived ideas and resulting in the generation of the present complex tooling.

As the entire project was aimed at exploratory development to determine the feasibility of an expandable rigidizable external aircraft fuel tank, the tooling design and the processes for fabrication to accomplish this task were also, to some degree, exploratory. Some of the experimental studies for gaining better insight into the materials from which most of the tooling was manufactured are discussed in preceding subsections. Also, some of the processes, adopted for the first time in the industry for a program of this magnitude, will be described in the following subsections.

The entire tooling concept, tool design and fabrication were based on the fact that only two prototype tanks were required. All tooling, therefore, was "soft" or non-productive type. Also, at the very early stages of this program, it was ascertained that the only tools to be delivered to the Air Force consisted of the final female curing tool, hence only this tool was built to stand shipping. The remainder of the tools and, in some cases, their supports were constructed without consideration of any shipping and/or longevity.

In addition to the exploratory tests of tooling materials, the tool design, and the fabrication processes, a certain amount of research and engineering work was necessary to develop the particular dual purpose bladder bag, needed for both application of positive pressure and its use as a male mandrel.

2. Tool Design Considerations

For the fabrication of the collapsible tank with all its appurtanances and the test specimens discussed earlier in this report, three types of tools were developed as follows:

a. Exploratory Test Specimen Tooling
b. Final Full Scale Tank Tooling
c. Peripheral Component Tooling

Each one of the above three tooling categories consists of several different types and sizes of tools which are the result of numerous trade-off studies in tooling concepts and tooling design considerations. Figures 25, 28, and 66 through 75 inclusive represent the design drawings and details pertaining to all the above tools and should be referred to as deemed necessary.

a. Exploratory Test Specimen Tooling

In fabrication of test specimens for the exploratory test phase of this program three types of tools were designed and made:

(1) Cylindrical Test Specimen Tool
(2) Conical Test Specimen Tool
(3) Bolting Ring and Pan Lay-up Tools

Both the cylindrical and the conical test specimen tools were internally pressurized female tools, employing vacuum-bag technique and autoclave pressure curing. The bolting ring and pan lay-up tools were lathe turned wooden tools.

(1) Cylindrical Test Specimen Tool

The cylindrical test specimen tool consisted of two aluminum cylindrical half shells with 22-inch diameter and 36-inch length. The cylindrical half shells were stiffened by two semicircular angle stiffeners one at each end. These shells were attached to each other by means of quick release bolts through additional flanges on both sides of the longitudinal edges.

The cooling process for the zone curing was accomplished by means of a water cooled chamber on the outside of one of the shells and water cooled coils on the inside of the test specimen. To maintain the same uniformity of heat dissipation on the inside of the test specimen as on the outside of the tool, a metallic cooling jacket or caul sheet was placed between the cooling coils and the cylindrical test specimen. The cooling coils and caul sheet can be seen partially in Figure 31 and full details are shown in Figure 25.

(2) Conical Test Specimen Tool

For the fabrication of the conical test specimen two conical tools were constructed. Both tools were similar in design, but different in materials of construction.

The first conical tool was manufactured from "Aluminum powder filled epoxy resin" composite. However, after the manufacture and cure of the conical test specimen, bolting ring and pan, the conical test specimen was crushed in the cooling cycle due to the difference in the coefficients of thermal expansion of the two materials. Subsequently, another conical tool was manufactured from impregnated tank material, which eliminated the thermal expansion problem as shown in Figure 28.

Since the B-staging, zone curing and final curing cycles in cylindrical and conical test specimens and tools were similar, an attempt to evaluate the cooling of collapsible portion in the zone curing process of the conical tool were made. Hence, instead of cooling the specimen both from outside and inside (as in the case of the cylindrical test specimen) only inside cooling coils were used. Also, for heat dissipation into the cooling coils aluminum foil, instead of caul sheet, was wrapped around the coils and shaped to fit the conical specimen, as shown in Figures 41 and 43. From the results obtained by this method and described in the preceding subsections, it was learned that cooling both sides of the test specimen is excessive and unnecessary. A minimal cooling on either side gives satisfactory results. This finding is incorporated in the design of the final female curing tool.

(3) Bolting Ring and Pan

Two pieces of lathe-turned wooden tools were prepared for use as male mandrels for the lay-up and fabrication of the bolting ring and pan, respectively. The shape and dimensions of these mandrels were in accordance with the drawing in Figure 28. The tools are shown in Figure 67 and 74. Only one set of these tools was made for this exploratory test phase, i.e. the tools required for the fabrication of aft end bolting ring and pan. The forward end bolting ring and pan tools, being similar to the above except for size, are manufactured only for the full scale tank fabrication.

b. Final Full Scale Tank Tooling

The tooling design for the production of the full scale tank has evolved around two main concepts: 1) a removable male mandrel for the lay-up of the tank and 2) a pressurized female tool for the final curing and rigidization. To materialize these ideas a conceptual tooling breakdown with step-by-step operations and a parts flow diagram, as shown in Figures 65 and 74, respectively, were generated. To summarize, a silicone bladder bag was developed to conform to the internal dimensions of the tank. The bag was

inserted into a male mandrel forming tool, a tower, and filled with ceramic granules, under vibration and low pressure. Immediately after the filling operation, the bag and granules now constituting the male mandrel, were removed from the tower under vacuum. After the lay-up of the tank material, both the mandrel and the raw tank were placed inside of a final female curing tool. B-staging, zone-curing and eventual rigidization of the tank were accomplished under specified pressures and temperatures.

To accomplish the operations above and fabricate the main body of the tank, five major tools were required:

(1) Two Plaster Male Mandrels
(2) Silicone Bladder Bag
(3) Male Mandrel Forming Tower
(4) Male Mandrel For Tank Lay-up
(5) Final Female Curing Tool

Smaller peripheral tools were also needed to produce detail parts, such as saddle-door, bulkheads, etc., some of which were the by-products of the above mentioned major tools.

(1) Two Plaster Male Mandrels

Two full length, round, plaster male mandrels were constructed to conform to the dimensional levels of control. The first plaster male mandrel was controlled to the interior dimensions or mold lines of the tank minus certain thicknesses. The second mandrel was controlled to the exterior mold lines of the final tank. Both mandrels were similar in construction, in that a wire mesh roll was fastened to steel supporting rings which, in turn, were welded to a square steel pipe shaft as the central supporting structure. Both ends of the steel shaft were supported by trunnion bearings, and the entire substructure was turned by a chain driven electrical motor.

The supporting structure was splined with a subcoat and several finish coats of plaster as it was turned. A full length aluminum template was used to establish the mandrel mold lines. Both ends of each mandrel were fitted with turned wooden fittings to allow for bolting ring and pan connection steppings. The center saddle door depression was splined with plaster to obtain the proper surface for each mandrel. The plaster male mandrel, which was controlled to the inside dimensions of the tank, also had allowances for tank material thicknesses, bladder bag thickness, and the vacuum compaction of both tank material and male mandrel granules. This mandrel was needed to construct the Male Tool Forming Tower described on the following page. The design and details for both of the above mandrels are shown in Figures 66 and 74, respectively.

Since 90% of the tools for this program, including the bladder bag, were generated from the initial male plaster mandrel, it was necessary to establish more accurate master lines. The basic dimensions of the tank, radius, and slope for every five inches of tank obtained from Equation 1 were used as input to a conic generator program using interpolation techniques, to obtain the data for every inch of the tank station. The program was specifically developed for Recomp II electronic digital computer, and the results are shown in Table XX.

(2) Silicone Bladder Bag

The involved process of using the bladder bag as the molder of the male mandrel prior to tank lay-up and its use as a pressure application device during the different phases of curing after the completion of the lay-up, necessitated certain developmental work to assure the success of all the above mentioned operations.

Due to the fact that the male mandrel was constantly under vacuum during the lay-up, it was mandatory for the material from which the bladder bag would be manufactured and the bag seams, etc. to be devoid of any pores. After several unsuccessful tries with overlapped vacuum bagging materials, bonded joints and other methods, it was decided to mold the bladder bag. Several combinations of RTV silicone molding compound were used and the best results were obtained from the following:

93-072 RTV Silicone Molding Compound	72.7%
93-076-2 RTV Silicone Molding Compound	18.2%
92-072 Hardener (catalyst)	9.1%

The above mixture was splined over the plaster male mandrel (controlled to the inside dimension of the tank) minus 1/8 of an inch for the bladder bag thickness. With the aid of a metal template and the turning mandrel, the raw bladder bag was formed. Both ends of the bag were reinforced by imbedding glass cloth in the molding compound. The entire assembly was put into an oven, and the turning of the mandrel continued throughout the duration of bag curing, i.e., 170°F for three hours.

(3) Male Mandrel Forming Tower

The Male Mandrel Forming Tower shown in Figures 67 and 76 was constructed using room temperature cured Furane-2V resin and chopped fiber spray-up system. The mandrel described in the above paragraph

was coated with Resolin 111 Surface Coat and used as a basis for the spray-up construction of the tower. Steel reinforcement was used on the outer stiffeners to stabilize the tower on the vibrating platform.

The silicone bladder bag was mounted on a steel center post inserted inside the tower tool and inflated with 5 psi pressure to adhere to the inside surface. The tool was used in a vertical position on top of a vibrating platform to allow the "SCR-Veri-Lite" ceramic granules to be introduced and compacted in the bladder bag. For easy removal of the plaster male mandrel and the tank lay-up male mandrel, the tower tool was constructed from two longitudinal half-shells. A make-shift sealed hopper was used to contain the granules prior to filling the bladder bag.

(4) Male Mandrel for Tank Lay-Up

After the silicone bladder bag was systematically filled and compacted with the "Veri-Lite" granules, the 5 psi pressure was removed and vacuum was applied to the center post and bag assembly. The air was drawn from small orifices in the central shaft thus forming a free body solid male mandrel to be used for the tank lay-up.

This male mandrel was positioned horizontally on a supporting dolly fabricated specifically for this purpose to facilitate the lay-up of the tank material circumferential gores. An indexing plate was used on the trunnion shaft to establish the tank centerline. The silicone bag male mandrel is shown in Figure 77.

The details of the different operations required for assembling the bladder bag over the central shaft, bag and shaft insertion into mandrel forming tower, filling of the bag with granules, reversing the pressure from positive 5 psi to vacuum, and finally removing the male mandrel from the tower and positioning it for lay-up are compiled as "Sequence of Operations for the Mandrel Forming Tower" and are included as Appendix VI.

(5) Final Female Curing Tool

The final female curing tool was, by far, the most complex tool fabricated for this project. The complexity of this tool stemmed from the fact that, in addition to final curing and rigidization of the main body of the tank, it also was used for the B-staging of the collapsible portion of the tank and zone curing of the hardback land area.

The final female curing tool was constructed in two half-shells from high temperature glass fabric laminated structure. The plaster male mandrel representing the exterior mold lines of the tank was used for the lay-up of the above material to a thickness of 1/2-inch. In the top half-shell allowances were made for the saddle-door and hardback land area.

Seven bulkheads, fabricated from the same material, were used to stiffen each half-shell. These bulkheads in turn were attached to rectangular frames on rollers. The frames were constructed from six inch steel square tubing and provisions were made with welded angles to tie both halves of the final female curing tool with steel bolted rods passing through these angles. The top half of this tool with saddle-door impression is shown in Figure 78, and the bottom half in Figure 79. The design drawing and pertinent details are shown in Figure 68.

This complicated tool was designed with the dual concept of its use inside and outside of the oven and/or autoclave. The zone curing or partial curing of the hardback land area which was performed outside of the oven, was accomplished by means of electrical elements imbedded in both half shells of the tool. The location of these electrical elements were predetermined and water cooling coils were placed immediately adjacent to them to prevent the heat transfer beyond the hardback land area. The water cooling coils were manufactured from square copper tubing to create more contact area with the tool, thus attaining better control of heat dissipation.

The B-staging and the final cure were performed inside an autoclave. For this reason, the entire tool was equipped with thirty thermocouples, positioned in various portions of the tank and tool for monitoring the several different stages of heating involved in all the above operations.

The numerous steps required for the proper operation and functioning of the final female curing tool, through the stages of zone curing, B-staging and final rigidization are discussed in the "Sequence of Operation for Final Cure" which is included as Appendix VII.

c. Peripheral Component Tools

In addition to the above major tools used to manufacture the main body of the tank, several smaller tools were required to fabricate the attached components. These peripheral component tools or minor dies are:

(1) Saddle-Door Hardback Lay-Up Die
(2) Hardback Land Area Lay-Up Die
(3) Bulkhead Clip Lay-Up Die

(4) Bulkhead Bonding Jig
(5) Bulkhead Installation Tool
(6) Bolting Ring and Pan Tools

All of the above dies were simple tools and each one served only one function. Rather than categorizing a separate description for each one, a generalized description follows.

The saddle-door hardback lay-up die was used to fabricate the removable hardback and was constructed from the same material and thickness as the final female curing tool. Its basic configuration is considered a male tool controlling the stepped-side or inside mold lines of the removable hardback. This tool was molded from a female plaster splash taken from the internal male plaster mandrel of Figure 66. To the above male tool a spanner frame of exposy resin and glass fabric was attached in tube form, by bonding. A female caul plate, approximately 1/16-inch thick was used to smooth the external mold line of the door in the process of curing. This tool is shown in Figure 81.

The hardback land area lay-up die was used to manufacture the precured ring receiving the saddle-door. The construction of this tool was very similar to the saddle-door tool in material and dimensions, with allowances made for seven plies of tank material on the inside surface. The original spanner frame was aluminum. Due to the differences between the thermal expansions of aluminum and epoxy resin glass fabric laminate, the spanner frame was refabricated from the latter material and attached to the male tool by bonding.

The bulkhead clip lay-up die, the bulkhead bonding jib, and the bulkhead installation tools were machined from aluminum. Their dimensioning was based on the same models used in the production of the major tools. This method of dimensioning was used to achieve perfect fit between the bulkhead components and the main body of the tank. Figures 71, 72 and 73 show the details and the drawing of the above components.

Two sets of bolting ring and pan tools were fabricated from lathe turned wood. These tools, having the configuration of male mandrels, were used to produce components for the attachment of nose cone and tail cone of the tank. Both sets of tools were similar in shape and concept, and were different only in dimensions. All the above lathe turned wooden tools were made to match the dimensions of the detailed drawing on Figure 55. The wooden tools for the aft bolting ring and pan are shown in Figure 80.

G. FABRICATION

1. Discussion

The fabrication phase of this contract began with the finalization of full scale tank design and analysis, the completion of all tooling, and the subsequent approval of all the concepts and considerations by the Air Force and Monsanto Research Corporation representatives.

The manufacture of the tank test specimens and other peripheral test components with the results of their tests are discussed in the Exploratory Test Phase - Subsection D. In this subsection, only the fabrication of two complete prototype tanks with all their components will be described.

This program required the fabrication of two expandable and rigidizable prototype tanks with the following difference: one tank would go through all the different cycles of curing and be completely rigidized, cured and assembled, but the second tank would be zone cured, B-staged, and collapsed only.

Both tanks would have finished components such as saddle-door hardbacks, bulkheads, bolting rings and pans. The saddle-door hardbacks would be assembled to both tanks prior to shipping. However, the bulkhead, bolting ring and pans would be assembled only to the final cured tank. The parts flow diagram in Figure 91 fully describes the various phases of manufacture of the two tanks and indicates the chronology and the state of deliverable items.

The tank material was preimpregnated by Monsanto Research Corporation and the pertinent Material Specification and Process Specifications were supplied to North American Rockwell Corproation and are included in this report as Appendices III and IV, respectively. These specifications were the bare minimum requirements for processing, and as the tank design and tooling developed, a new, all inclusive manufacturing process specification also was prepared. This process specification is included in this report as Appendix V.

2. Manufacture of Components

a. Saddle-Door Hardback

The first of a total of three saddle-door hardbacks was fabricated using tank material in accordance with the details and dimension of the drawing in Figure 50. Vacuum bag compaction was applied after each four ply lay-up, starting with the bottom skin and building

up the thicknesses as required. The lay-up, use of adhesives, bonding of flexicure and the final cure were performed in accordance with the above mentioned process specifications. Figure 85 shows the hardback tool partially laid-up with the bottom skin.

It was observed that the final cured part had excessive delaminations and the solid core areas had developed marked corrugations around the edges. Due to these undesirable features and the fact that the choice of material for the fabrication of the hardback was optional, it was decided to change the material to 181 E-glass, Epoxy Resin system.

Two additional saddle-door hardbacks were fabricated (one for each prototype tank) from epoxy-resin impregnated 181 E-glass fabric. The results were satisfactory and these hardbacks were used on the final tanks as shown in Figures 90 and 98. A metal template was used to orient the bolt locations. The bolt holes were drilled through the saddle-door hardback and the hardback land area simultaneously.

b. Main Body of the Tank

In the design of the full scale tank (subsection D above) the tank material gores were developed into flat patterns as shown in Figure 64. Since the maximum height of the frustum was limited to 15 inches, it was necessary to establish overlap locations and scatter them uniformily in order to avoid unwarranted build-up of thicknesses in the tank shell. This scattering of overlap locations was performed both in the longitudinal and transverse directions of the tank. In the drawing on Figure 92, all the gore part numbers with their respective overlap stations are called out. A sheet metal template was fabricated to conform with the stations shown in the above mentioned drawing and used for orienting the gores in the process of lay-up.

The full size drawings of Figure 64 were used to prepare metal templates which in turn were used to precut two sets of the tank material for the lay-up of the two tanks.

(1) Fabrication of Tank Body 1

Prior to lay-up of the tank the solid core of the hardback land area was laid-up on a separate tool as shown in Figure 82. This part was precured before assembly, then imbedded in the lay-up of the tank. This was accomplished by allowing one half of the total number of plies to go under and the other half to go over the precured part.

The tank gores were laid-up on the horizontal male mandrel while it was under vacuum, and the wet laminate was compacted by vacuum bagging after each four ply lay-up. Some difficulty was encountered in the

adhesion of the tank material to itself and to the silicone bag of the male mandrel, in the process of lay-up. In these cases, the gores were held in place temporarily by means of adhesive tapes. Also, due to thermal expansion, there was a marked dimensional mismatch between the precured solid core of the hardback land area and the allowed depression of the male mandrel for this component. The final stage of the compaction by vacuum bagging and some of the adhesive tapes are shown in Figure 83.

Both halves of the final female curing tool were treated with the parting agent (recommended by Monsanto Research Corporation) prior to placing the wet lay-up in them. The Tank No. 1 lay-up assembly together with the male mandrel, while the latter was still under vacuum, were placed into the half-shell of the final female curing tool as shown in Figure 84, and then covered with the other half.

The zone curing and B-staging of this tank was accomplished in accordance with the Process Specifications and Sequence of Operations set forth in Appendices V and VI, respectively. A great deal of difficulty was encountered in releasing the B-staged tank from the female tool. A new parting agent was then developed and tested as discussed in Exploratory Test Phase - Subsection D, (pages 21 and 22). Figure 86 shows this zone cured and B-staged tank, after the removal of the male mandrel and bladder bag from its inside.

The collapsing of this tank was accomplished as follows. First, a central fold was introduced from the bottom of the tank toward the saddle-door area, as shown in Figure 87. Then the forward and the aft ends were folded into the central portion of the tank thus completing the collapsing phase of the tank. The top and bottom views of the collapsed tank are shown in Figures 85 and 88, respectively, and the completed collapsed tank with assembled hardback appears in Figure 90.

(2) Fabrication of Tank 2

Experience gained in the manufacture of the first tank was applied to the fabrication of the second tank, where applicable. At the outset, the interior of the two half-shells of the male mandrel forming tower, were built-up to a thickness of 0.020 in. with two layers of 181 E-glass fabric. The purpose of this reduction (0.040 in. in the diameter) of the male mandrel and, consequently, the tank shell was for easy removal of the part from the final female curing tool.

Secondly, the solid core of the saddle-door land area was not precured for this tank, as it was done for Tank 1. Instead it was laid-up, vacuum bag compacted and B-staged only. This B-staged solid core was imbedded in the shell skin during the tank lay-up process.

All the steps of the fabrication of Tank 2, up to the collapsing point, were similar to that of Tank 1, except as noted above. The use of the newly developed parting agent greatly facilitated the B-staged part removal from the final female curing tool.

After the collapsing operation the Tank was unfolded and expanded by introducing a small amount of pressure in the bladder bag. The B-staged, expanded tank shell and bladder bag were placed inside the final female curing tool for the second time. Both halves of this tool were treated again with the new parting agent prior to placing the tank in them.

The entire assembly was put into an autoclave, and after connecting the thermocouples and water conduits the tank was cured in accordance with Process Specifications in Appendix V.

c. Bulkheads and Slosh Baffles

In addition to shell stiffeners, the bulkheads also served as anti-slosh devices, to prevent the unwarranted center-of-gravity shifting from fuel sloshing. The bulkheads were sandwich panels fabricated from epoxy resin impregnated 181 E-glass fabric and aluminum core. For the manufacture of each set of two bulkheads, one large integral panel, approximately 3 ft x 6 ft was laid-up and cured. The exact shape of the bulkheads then routed on this panel to conform to the dimension of the drawing in Figure 51. The slosh baffles consist of two unimpregnated and uncured layers of 181 E-glass fabric imbedded in the edges in four precured circular laminates. This assembly was bolt connected to the stiffening bulkhead. Two circular holes were precut in the bottom part of the bulkhead to minimize the effect of the hydrostatic fuel head build-up on either side of the slosh baffle. One of the four cured bulkheads, with slosh baffle and attachment clips is shown in Figure 95.

d. End Attachments

Two sets of two bolting rings and pans were manufactured in this program, one set for each tank. Since the choice of material for these components was optional also, based on the experience gained in the manufacture of test bolting ring and pan specimens from the tank material, it was decided to fabricate these components from epoxy resin impregnated 181 E-glass fabric

To conform with the shell thicknesses obtained from the stress analysis, the aft bolting ring and pan were manufactured from nine plies of fabric. First, the bolting ring was laid-up on the male mandrel shown in Figure 80. The nut plates were attached after the above ring was cured. Then, the pan was laid-up, cured, and bonded to bolting ring.

The duplication of thickness at the bonding interface was intentional in order to achieve additional stiffeners at either end of the tank. The fabrication of the forward bolting ring and pan was identical to that of aft end except six plies were used, again to be compatible with the previously obtained shell thicknesses. The outside and inside views of one set of bolting ring and pan are shown in Figure 93 and 94, respectively.

e. Miscellaneous Components

Since the suspension lug bushings, air pressure fitting, and water drain fitting could not be furnished either by Monsanto Research Corporation or by the Air Force as initially required, it was necessary to fabricate these components to better simulate the metal tank. The air pressure and water drain fillings were machined from 7075-T651 aluminum bar stock, and the suspension lug bushings were machined from 7075-T6 bare aluminum alloy plate stock. These parts are shown in Figures 54, 56, and 53, respectively. One set of each component was fabricated for each tank.

3. Repairs

After the complete rigidization of the tank main body and its removal from the final female curing tool, several defective areas were observed which needed repairs. These repairs were of four distinct categories and, in all four cases, room temperature cured Bond Master M611 resin system with DTA catalyst was used. The room temperature cure was necessary due to unavoidable softening and deformation of precured part in reheating cycle. These four repair areas are:

a. Internal Blisters

On the inside of the final cured tank there were three spots where internal blisters had caused delamination of one or possibly two plies of tank material. The cause of these blisters is attributed to the fact that atmospheric moisture may have condensed in certain areas of the tank material just removed from the cooler. These three spots were approximately 3, 4, and 6 inches in diameter.

The above blisters were "peel-plied" and sanded in a step-wise manner to allow one inch overlap for each ply of uncured material for repair. Epoxy resin was injected in those areas prior to lamination and cured at room temperature.

b. Collapsing Fold Wrinkles

On both sides of the saddle-door hardback land area, at about stations 50 and 121 of the tank, wrinkles were created due to incomplete unfolding and interlaminar rolling of the tank material during the expansion process. These wrinkles were U-shaped in cross section and were rigidized in the process of final cure. The U-shape internal protrusions were ground off and the laminates on both sides of the remaining hole were "peel-plied" in a step-wise manner, sanded and layers of repair cloth laid-up as required by previously established shell thicknesses. The above repair areas are shown as shaded lines on Figures 97 and 98.

c. Mold-Line Dimples

On both sides of the tank main body where the two half-shells of the final female curing tool meet, there were two longitudinal dimples 1/4 inch wide throughout the length of the tank. These dimples were the direct result of excessive deflection in the flange of the female tool caused by pressure build-up and thermal expansion due to heat.

The repair of these dimples was similar to the repairs of collapsing fold wrinkle above, i.e., the external protrusions were ground off, the laminate was "peel-plied", sanded and repair cloth laid-up as required.

d. Saddle-Door Land Area Corrugations

The longitudinal portions of the saddle-door land area, i.e., the sides parallel to the main axis of the tank precured by zone curing, developed two one inch wide corrugations. This corrugation is believed to be the result of softening of epoxy base materials in the process of reheating.

The curvature of the corrugations being slight, they were smoothened by sanding and filling in gaps with M 611 - Bond Master where necessary. Additional repair cloth was laid-up on top and cured under vacuum bagged pressure.

4. Final Assembly

After performing all the above repairs on the main body of the tank, the tank shell and all the other components were ready for final assembly. All the parts were dry fitted first to assure perfect fit. A limited amount of sanding was necessary.

The groove for the O-ring seal of the saddle-door was routed in the hardback land area next. Nut plates were riveted to the inside of the hardback land area and the saddle-door was positioned and bolted into place. The bulkhead and slosh baffle assemblies were positioned and bonded to the tank with precured clip angles and adhesive as specified in Process Specification, Appendix V. The inside view of the tank with bulkhead and slosh baffle bonded in place is shown in Figure 96.

The nose cone and tail cone bolting ring and pan assemblies were bonded to the main body of the tank in accordance with the above mentioned Process Specification. This assembly can be seen in Figure 97.

The cavities or depressions remaining around the saddle-door and end attachments after assembly were filled with aerodynamic filler for smoothness. The final rigidized tank with complete assembly is shown in Figure 98.

H. CONCLUSIONS AND RECOMMENDATIONS

The objective of this study has been to conduct exploratory development of an expandable rigidizable external aircraft fuel tank design in order to determine the feasibility of such a concept.

With the successful production of the test specimens, the test tools, the full scale fabrication tooling, and the two prototype tanks and their results, it is concluded that although all of the above mentioned tasks were to some degree exploratory, the construction of collapsible, expandable and rigidizable tanks and/or structures is in the realm of possibility. This feasibility conclusion is based on (1) the demonstration of a concept by its physical production; and, (2) the pro and con experiences gained in regards to the factors affecting the successful materialization of such a concept.

Although the above conclusion is significant the results clearly indicate the necessity of a more fundamental approach to the considerations given to the design, the analysis, the tooling, and the fabrication of this type of structure in the actual production. The following recommendations are made in a systematic fashion following the order of the headings appearing in the outline of this report.

1) Improvements and optimizations can be made in the design concepts to increase the nesting ratio and enhance the ease of collapsibility. For example, the saddle-door hardback subtending angle θ, can be reduced from the present 180° to a much smaller angle, thus attaining a higher nesting ratio. The extent to which this angle can be reduced is dependent on the buckling mode shapes of the tank shell and the results of stress analysis optimization.

The beveling of both ends of the saddle-door hardback and consequently the hardback receiving land area can be eliminated to increase nestability. This modification not only reduces the length of the hardback but also places the saddle-door in the cylindrical portion of the tank. Because of single curvature of the tank in this area, both tooling and fabrication tasks become simplified and economical.

Both reduced subtending angle and the rectangular ends of the saddle-door hardback, tend to facilitate the zone curing process, due to the fact thatonly one half shell of the final female curing tool need be imbedded with electrical elements. The above design concept improvement, in general, reduces the

complexity of including the saddle-door impression in both halves of the male mandrel forming tower, final female curing tool and minimizes the physical difficulties encountered in the lay-up process.

2) In the design of the full scale tank, it is possible to reduce the tank weight considerably or to eliminate the bulkheads altogether by means of improving the material properties. One way of accomplishing either of the above mentioned objectives is to investigate the possibility of using the present resin system in the filament winding technique, which increases the Young's Modulus of Elasticity considerably. This recommendation is based on the comparisons of data of several other epoxy base glass fabrics, and it is anticipated that the material used for this study will exhibit a similar improvement.

It is considered that, in addition to improved material properties and more advanced stress analysis techniques, a reliability study would also be in order. A higher confidence can be placed in a structure by a factor-of-safety method as is the case in the present study. In an individual component analysis a large positive factor and/or margin of safety is commendable, but, no matter what magnitude the factor of safety has, the actual reliability of the structure is never known. In contrast, the reliability design approach considers the statistical nature of the design factors and, in this way, requires not only a known reliability but also the confidence level associated with the statistical data utilized.

3) In the initial studies of a feasibility type program, sometimes, it is considered that "soft" or nonproduction tooling is more expeditious and economical. However, in the final analysis, the disadvantages associated with temporary and non-production type tooling, such as tool malfunctioning, repairs and fabrication of sub-standard production parts offset time and money saved, if any.

If the granules used for the formation of the male mandrel are blown into the bladder bag rather than being precipitated by gravity a great deal of time can be saved in the production process. The central manifold of the mandrel, used for evacuating the air from the granules, could be redesigned to allow faster filling and purging of modules after tank lay-up and compaction.

To minimize longitudinal deflections the side flanges of the final female curing tool half-shells should be increase in thickness and the distance between the attached bolts and interior edge of the flange should be reduced. It is also possible to prevent excessive deflections by intermittently strapping the two half-shells of the tool together These methods will eliminate the extensive, uneconomical, manual repairs of the produced parts.

The bladder bag used for the application of positive pressure should be either molded from a stronger material or be reinforced throughout its length to alleviate the damages brought about by its extensive use. Since the bladder bag is the focal point of several functions and is instrumental in the production of the major tools, its thicknesses at various stations of the tank should be more rigidly controlled.

4) In the manufacturing phase a great deal of time and labor will be saved if the number of gores are kept to a minimum. This objective can be achieved by a process of optimization and the automation in the layout of the gores and templates. It is also possible to accomplish the same result by changing the direction of the gores from transverse to longitudinal and pre-weave the cloth to conform with the tank mold lines.

Finally, instead of simulating the present metal tank, the entire tank, including internal plumbing and other external components and appurtenances can be redesigned to comply with the concept of collapsibility, expandibility, and rigidization. The plumbing should be redesigned to conform with the concept of the collapsibility of the tank.

APPENDICES

APPENDIX	I	Figures, Design Drawings and Details
APPENDIX	II	Tables I through XX
APPENDIX	III	Wing Tank Material Specifications (MPC)
APPENDIX	IV	Wing Tank Manufacturing Pricess Specifications (MRC)
APPENDIX	V	Process Specifications
APPENDIX	VI	Sequence of Operations for Mandrel Forming
APPENDIX	VII	Sequence of Operations for Final Cure

APPENDIX I

FIGURES, DESIGN DRAWINGS AND DETAILS

EXPANDABLE RIGIDIZABLE
EXTERNAL AIRCRAFT FUEL TANK

APPENDIX I
LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (cont'd)

LIST OF ILLUSTRATIONS (cont'd)

LIST OF ILLUSTRATIONS (cont'd)

LIST OF ILLUSTRATIONS (cont'd)

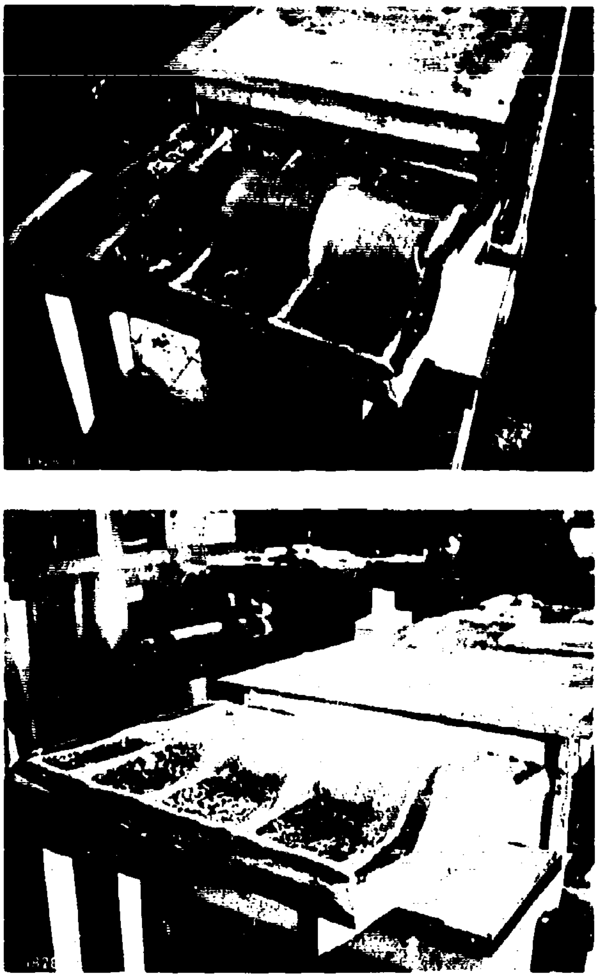


Figure 1. Female Mold on Plaster Model for AF Demonstration

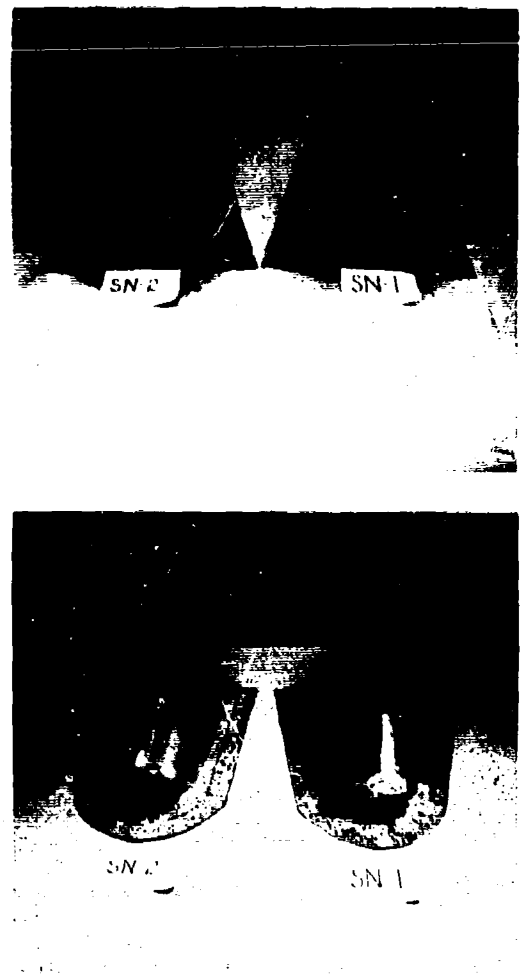


Figure 2. Molded Hardback (SN-1) Molded Thermoelastic Part (SN-2) for AF Demonstration

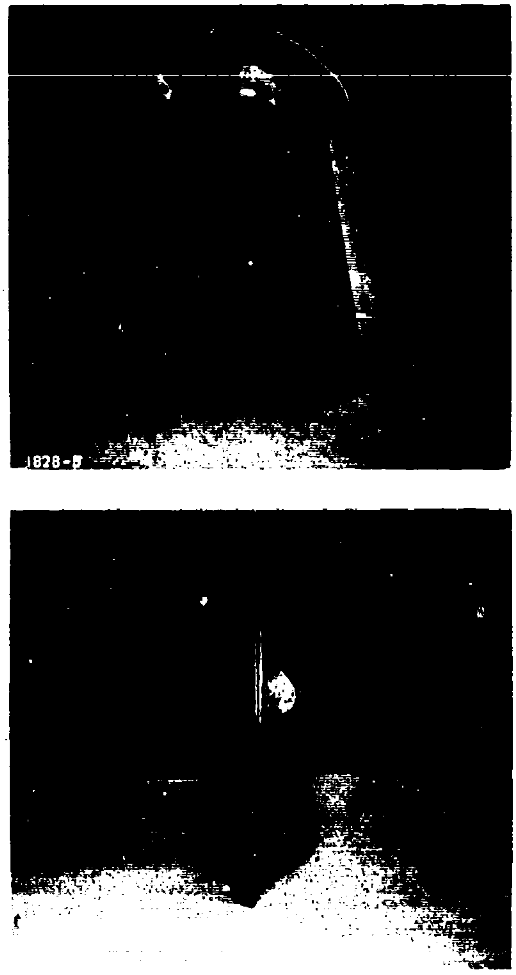


Figure 3. Assembled Hardback and Thermoelastic Nose Section for AF Demonstration

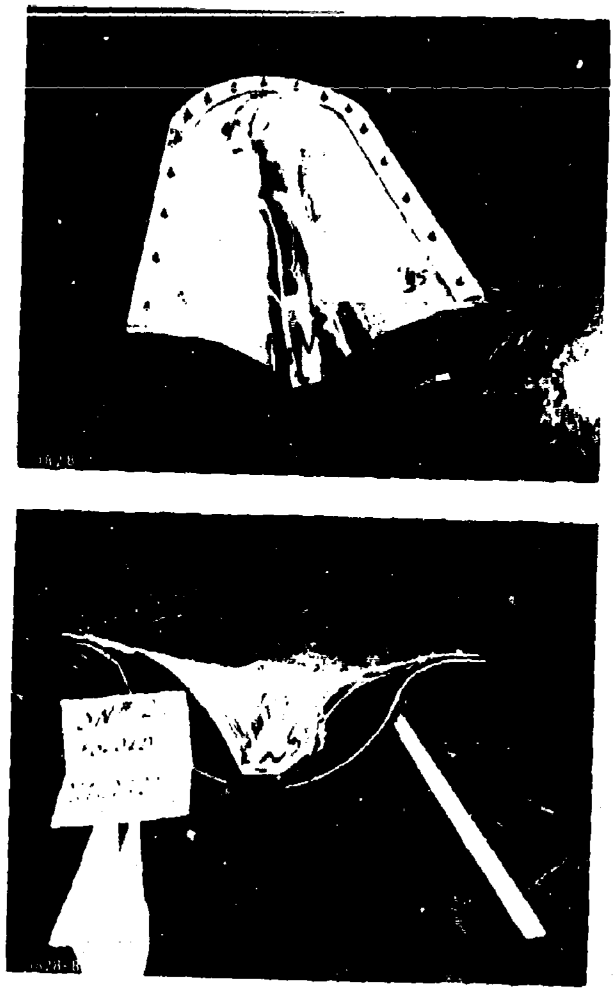


Figure 4. SN-1 and 2 Parts after Attempt Was Made to Fold the Thermoelastic Nose Section at Approximately 250°F for AF Demonstration

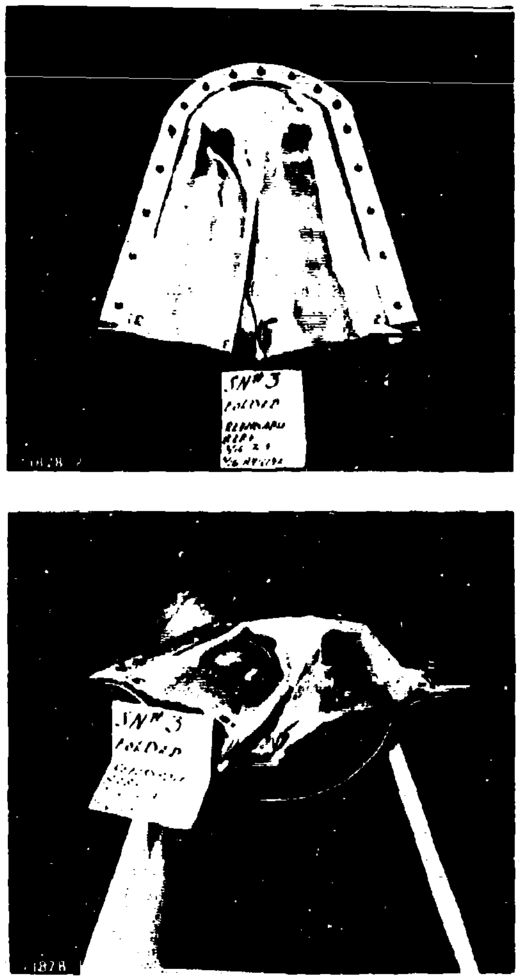


Figure 5. SN-1 and 3 Parts after Attempt Was Made to Fold the Second Thermo-elastic Nose Section at Approximately 250°F for AF Demonstration

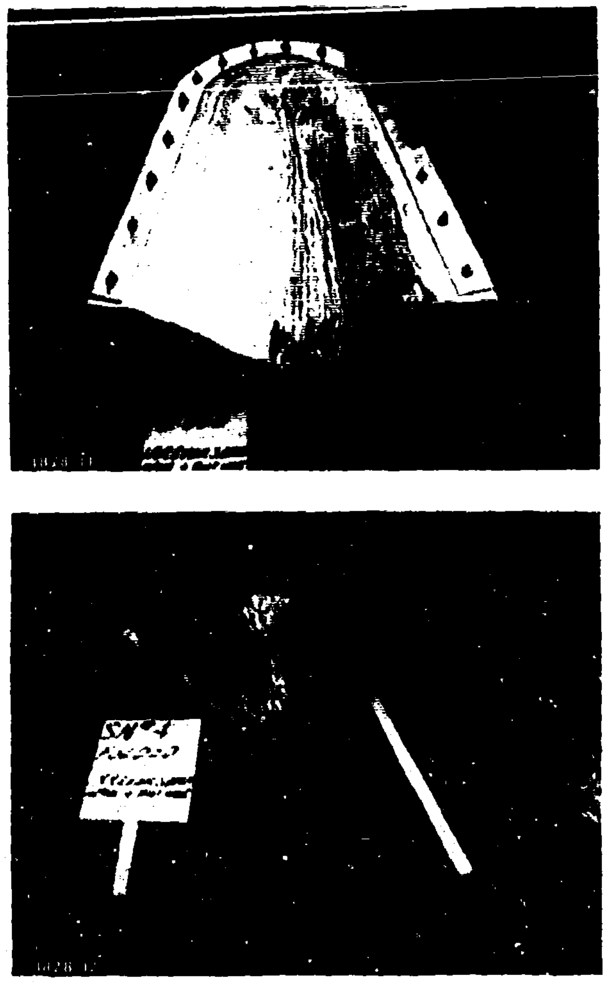


Figure 6. SN-1 and 4 Folded at Room Temperature for AF Demonstration

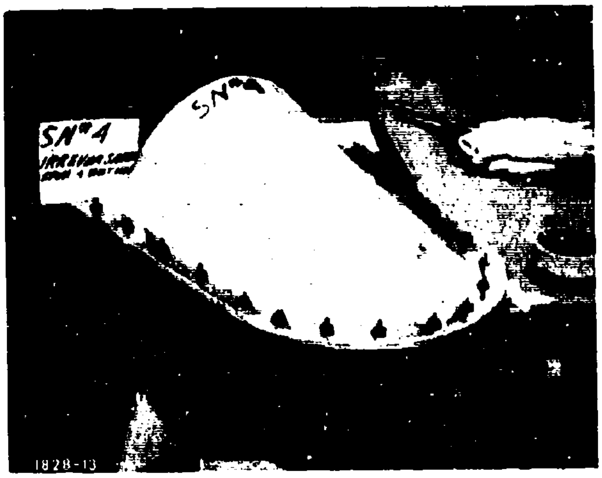


Figure 7. SN-1 and 4 Deployed after Being Folded for AF Demonstration

Ferro Corporation/Cordo Division
P.O. Box 2426, 1754 Telegraph Road
Mobile, Alabama 36601

CF-39
Rev. A

Attention: Purchasing Department Monsanto Research Corp.

Reference your P.O. D-40653 Dated 11/8/67

This is to certify that this material furnished on above order was produced in conformance with applicable specification and that test reports are on file subject to your examination.

Date 11/16/67

Product 817-PX26

Batch No 7063

Amount Shipped (Yds/Lbs.) 672
Width 38"

Date Mfg. 11/15/67

APPLICABLE SPECS: MRC-MS-001

REQUIREMENTS:

Resin % (Wet/Dry) 38±2

Volatiles % Report 15 mins @ 325 °F)

Flow % 14±3 (15 psi @ 325 °F)

Gel 4-9 (30 psi mins @ 325 °F)

Other Requirements: "Store at 40°F"

QUALITY CONTROL REPORT:

Resin % 37.7

Volatiles % 0.99

Flow % 14.8

Gel 4 mins 10 secs

Comments:

Date Shipped: 11/16/67

Very truly yours,

Charles R. Clark

Charles R. Clark
Quality Control Manager

Figure 8
Certification of MRC-MS-001 Material

CP-37 Revis...

FERRO CORPORATION, CORDO DIVISION

PRODUCT ROLL LOG

CUSTOMER Monsanto Research Corp. PRODUCT 917-PX26

ORDER NO. D-40653 BATCH NO. 7063

ROLL NO.	YARDS	RESIN CONT.	FLOW	VOLATILES	GEL
4342	50-15	37.7	14.2	1.04	4 6/10
4343	50	37.0		1.04	
4344	50	37.6	13.3	0.96	
4345	50-15	37.5		0.90	
4346	50	37.6	14.6	0.96	
4347	50	37.3		0.94	
4348	50-15	37.7	14.8	1.01	
4349	50	37.1		0.92	
4350	68	38.9	16.5	1.17	
4351	50-15	37.7		1.00	
4352	50	37.3	14.1	1.04	
4353	49	37.5		1.11	
4354	55-15	38.9	16.0	0.94	

Figure 9
Prepreg Product Roll Log

Figure 10. Spot Curing Using a Press

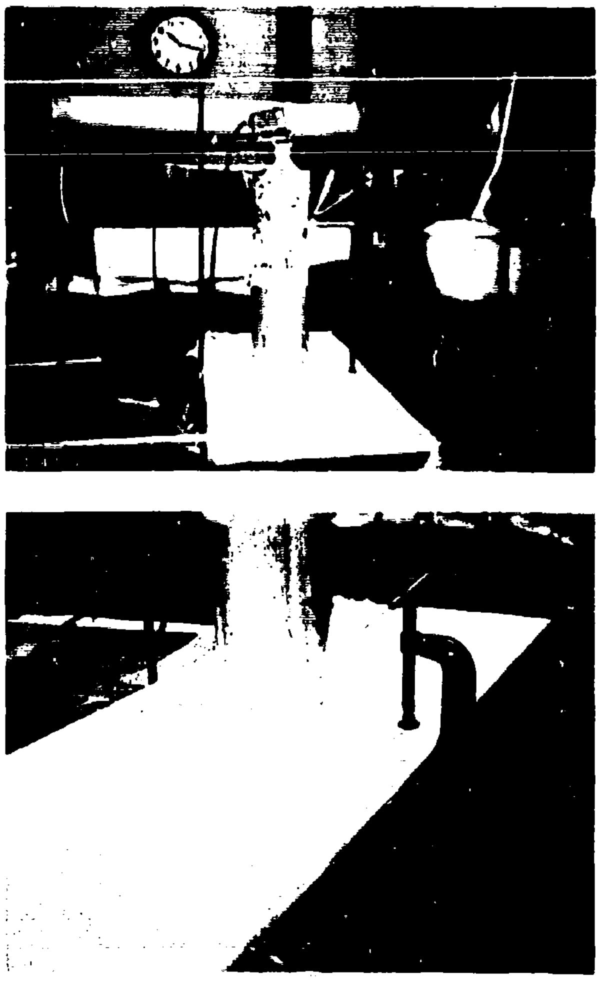


Figure 11. Spot Curing Using Infrared Light and Vacuum Bag Process

Figure 12. Spot Cured Specimens Using Press Molding Process

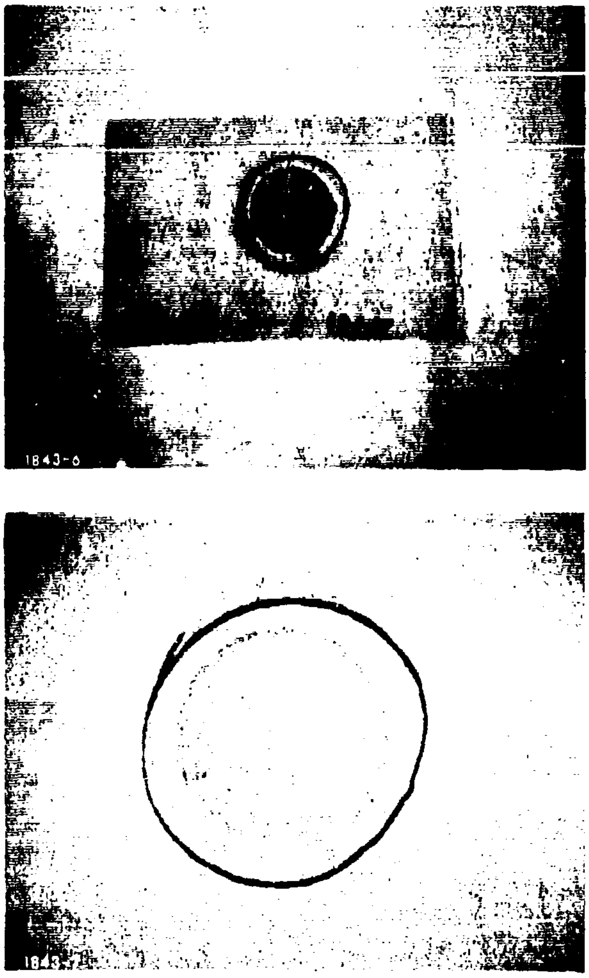


Figure 13. Spot Cured Specimens Using Infrared-Vacuum Bagging Process

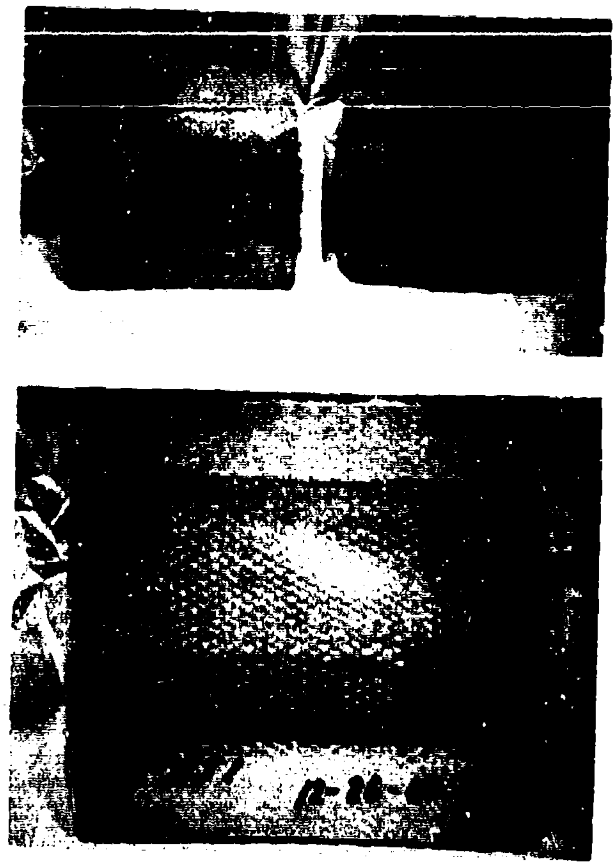


Figure 14. Zone Cured Honeycomb Panels

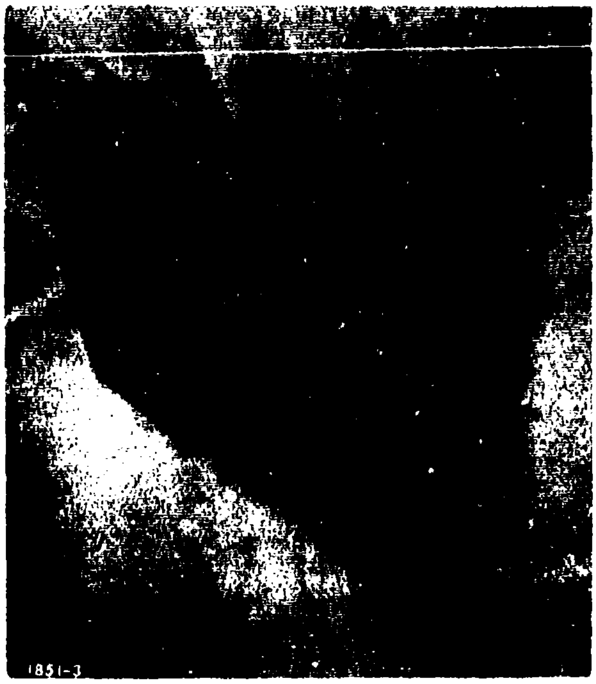


Figure 15. Folded Uncured Section of Zone Cured Honeycomb Panel

Figure 16. Front (Top) and Back Views of Molded Honeycomb Panel after Folding

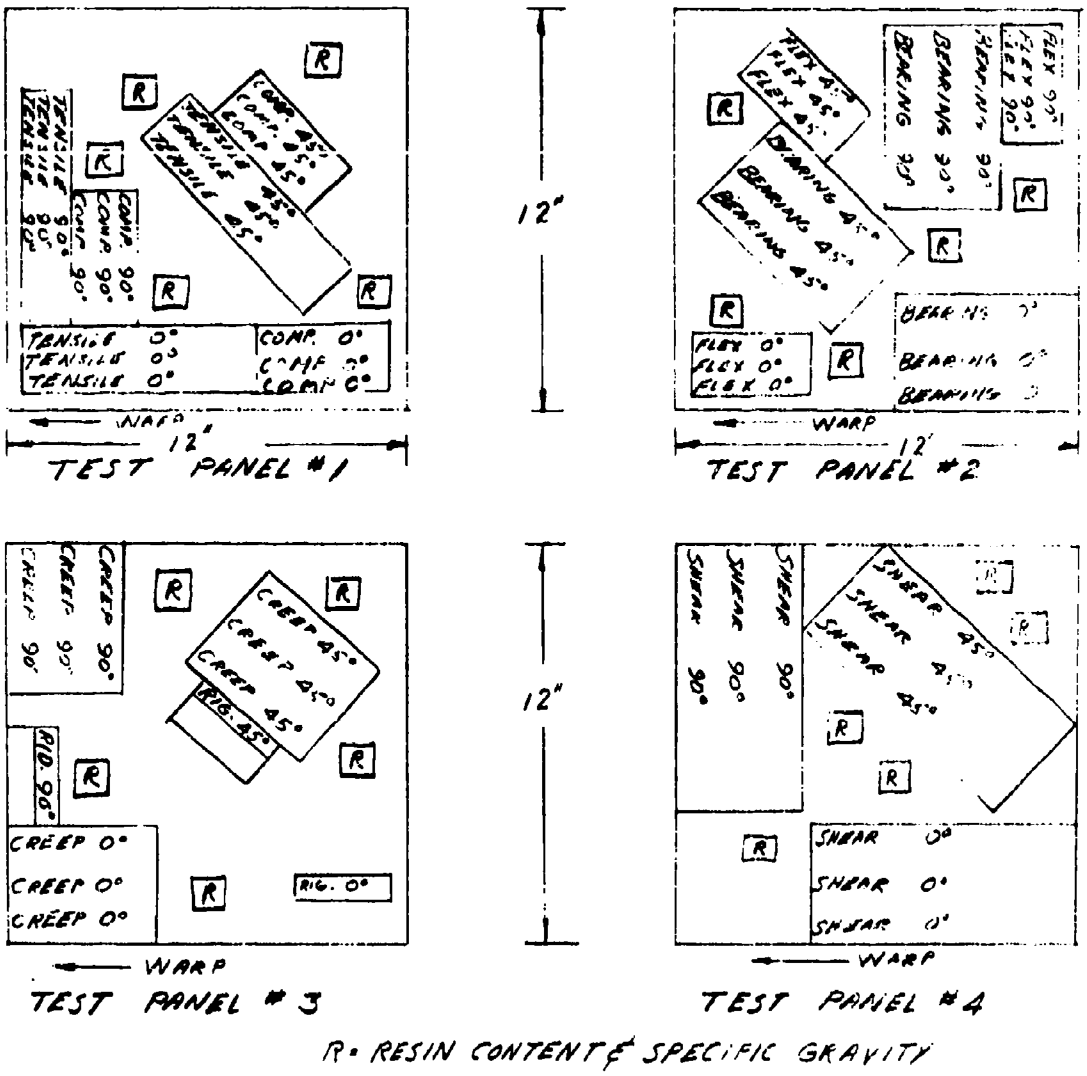
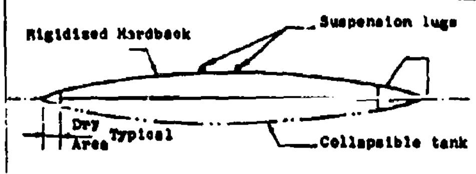
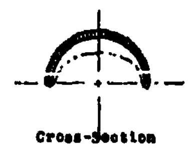
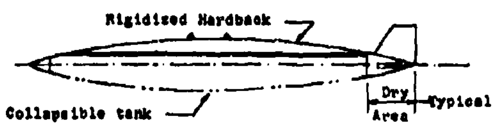
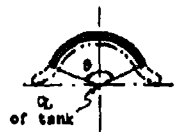
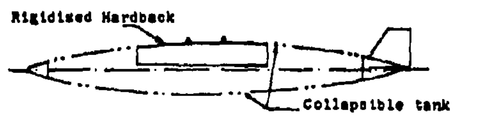


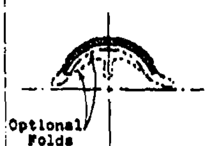
Figure 17 - Test Panel Layout

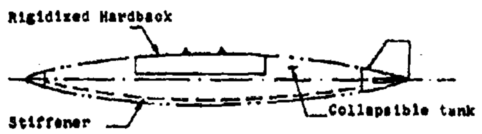
<table>
<tr><th colspan="2">DESIGN CONCEPTS AND CONFIGURATIONS</th><th>COMMENTS</th></tr>
<tr><td>

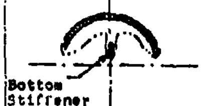
a.(1) - Full Length, Half Depth Hardback</td><td>
Cross-Section</td><td>This concept is advantageous from the stiffness and load carrying capability point. The full length hardback provides good support for the bottom half thin shell and distributes the load path uniformly. However the nesting ratio is jeopardised, 2 to 1 being the maximum, and the excessive hardback weight is another undesirable feature of this concept.</td></tr>
<tr><td>

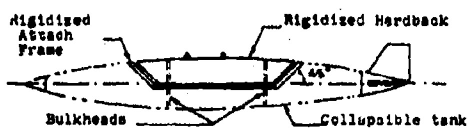
a.(2) - Full Length, Partial Depth Hardback</td><td>

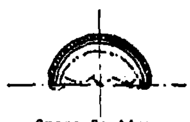
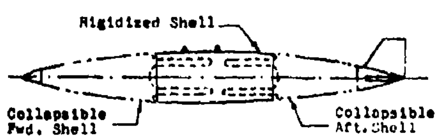
Cross-Section</td><td>This concept has the same advantages as a.(1) concept with improved nesting ratio of 3 to 1. Higher nesting ratios can be attained by design optimization in the reduction of subtending angle θ. The disadvantage of excessive weight of the full length hardback is still in existance in this concept.</td></tr>
<tr><td>

a.(3) - Partial Length, Partial Depth Hardback</td><td>

Cross-Section</td><td>Higher nesting ratios can be achieved in this concept due to increased collapsible area. Weight savings are realized due to the small size of the hardback. However due to low stiffness, thicknesses are increased thus jeopardizing the weight requirement.</td></tr>
<tr><td>

a.(4) - Partial Hardback with Bottom Stiffener</td><td>

Cross-Section</td><td>This concept has good load carrying capability and stiffness characteristics. However due to incollapsibility of the bottom stiffner the nesting ratio is limited to 2 to 1.</td></tr>
<tr><td>

a.(5) - Saddle-Type Hardback with Bulkheads</td><td>
Cross-Section</td><td>With the introduction of bulkheads and multiple folds a much higher nesting ratio can be achieved with this concept, maintaining structural integrity and minimum weight requirements.</td></tr>
<tr><td>

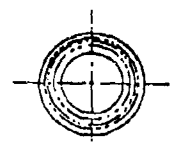
b.(1) - Bellowed Fwd. and Aft. Sections</td><td>
End-View</td><td>This concept offers 3-4 to 1 nesting ratio and a protective shell around the collapsible portion of the tank. However the multiplicity of the folds are undesirable and disadvantageous from the final curing point.</td></tr>
</table>

Figure 18 - Design Concepts and Configurations

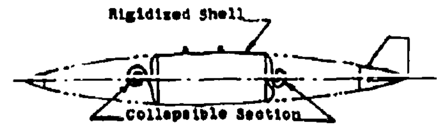
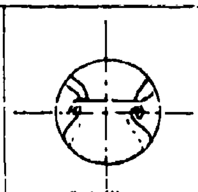
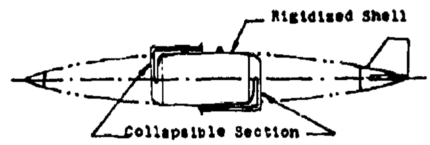
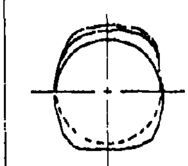
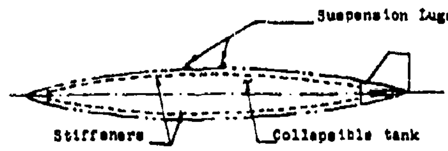
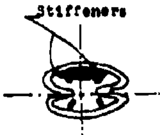
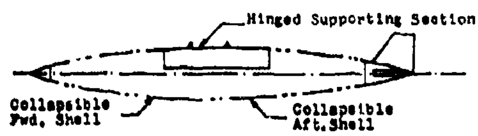
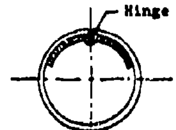
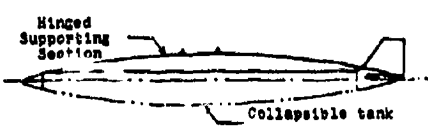
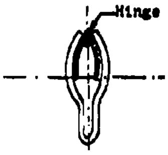
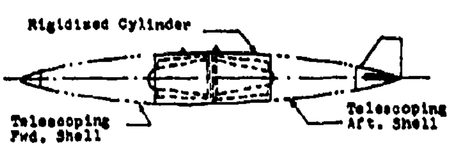
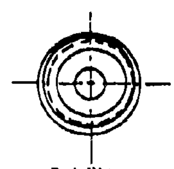
DESIGN CONCEPTS AND CONFIGURATION		COMMENTS
 b.(2) - Collapsed and Rolled Fwd. and Aft. Section	 End-View	In this concept it is intended to increase the nesting ratio by reducing the length of the rigidized shell. However, the resistance of the material to roll, and the delamination possibilities are the disadvantageous features.
 b.(3) - Folded and Overlapped Fwd. and Aft. Section	 End-View	The advantage of this concept is the same as concept b.(2). Resistance to roll and delamination possibilities are eliminated by overlapped folding which jeopardizes the nesting ratio by increased girt size of the tank and thus renders it undesirable.
 c.(1) - Longitudinal Stiffeners	Stiffeners  Cross-Section	By using longitudinal stiffeners good load carrying capability and weight reduction is achieved. However due to unfoldability of the stiffeners hardly any acceptable nesting ratio can be obtained.
 c.(2) - Hinged, Partial Length, Rigid Halves	Hinge  Cross-Section	The concept of the hinged supporting section can increase the nesting ratio considerably due to elimination of curvature in the rigid halves. However the intricacy of design and field erection problems offset the above advantage.
 c.(3) - Hinged, Full Length, Rigid Halves	Hinge  Cross-Section	The full length supporting section has better load carrying capability and stiffness, but in addition to the disadvantages of concept c.(2) it has the penalty of excessive weight and impracticality of hinging at double curvature areas.
 c.(4) - Telescoping Fwd. and Aft Rigid Sections	 End-View	The only advantage of this concept is the fact that the entire tank can be cured prior to shipping and only the attachments would be cured at the field. This is not within the scope of this contract and it is mentioned here as a suggestion for the future designs.

Figure 18 - Continued

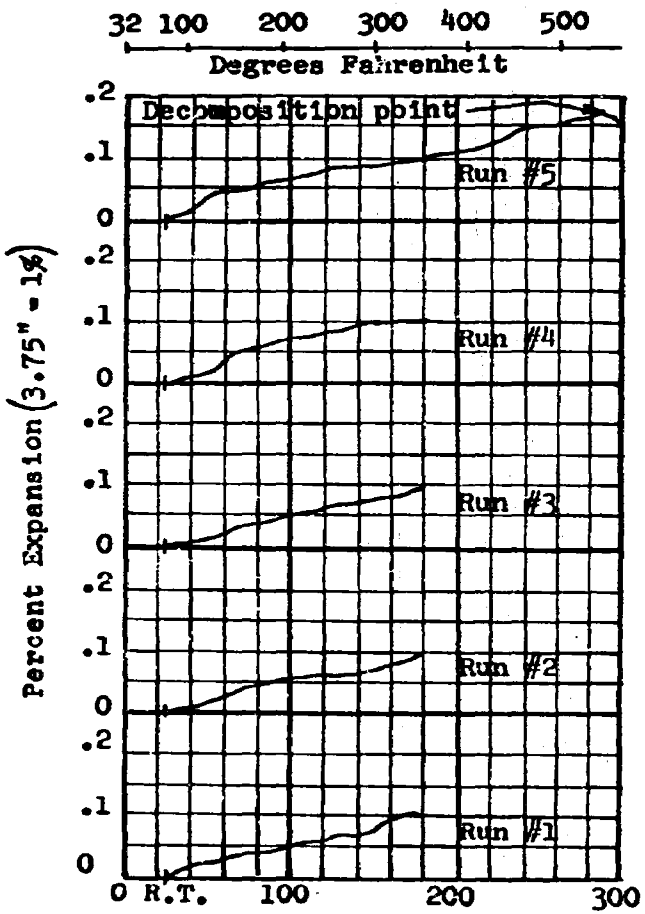


Figure 19 - Tank Material Thermal Characteristics

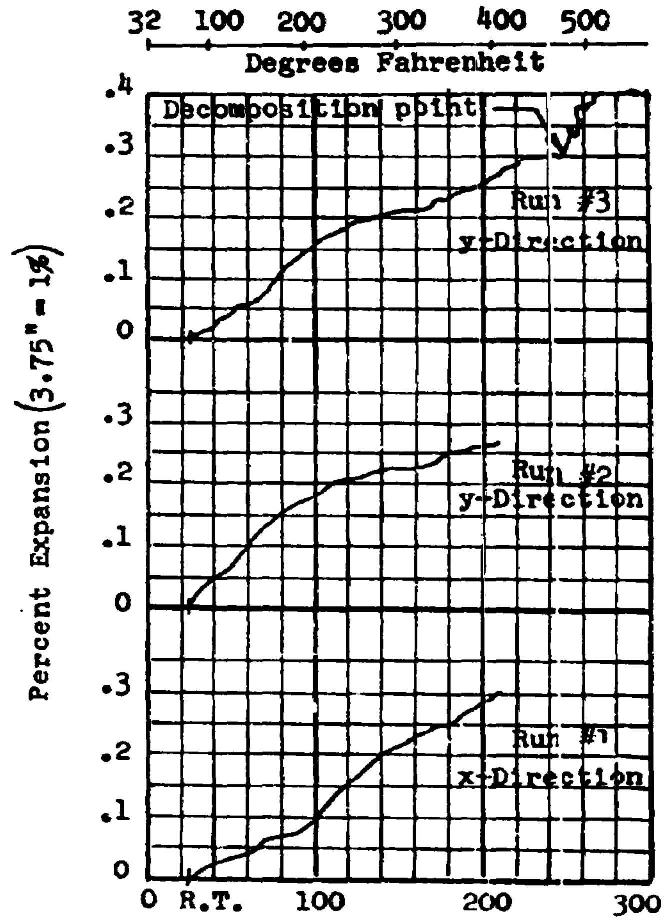


Figure 20 - Tool Material Thermal Characteristics

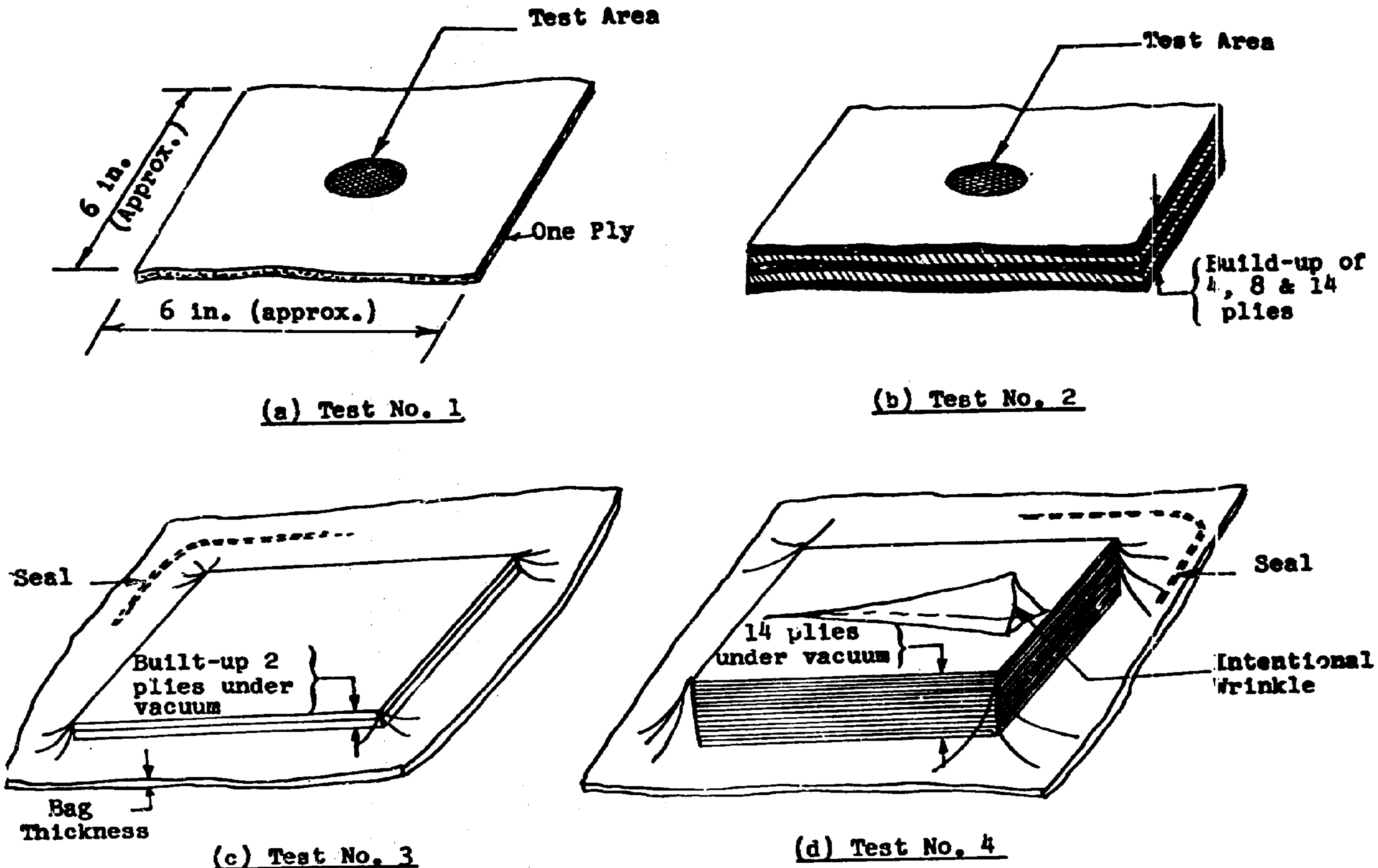


Figure 21 - Tank Material Compaction Test Set-ups

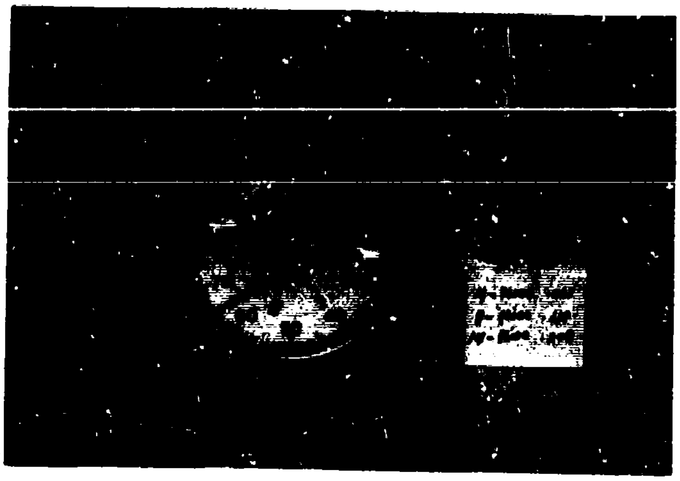


Figure 22 - Compaction Test Equipment and Set-up

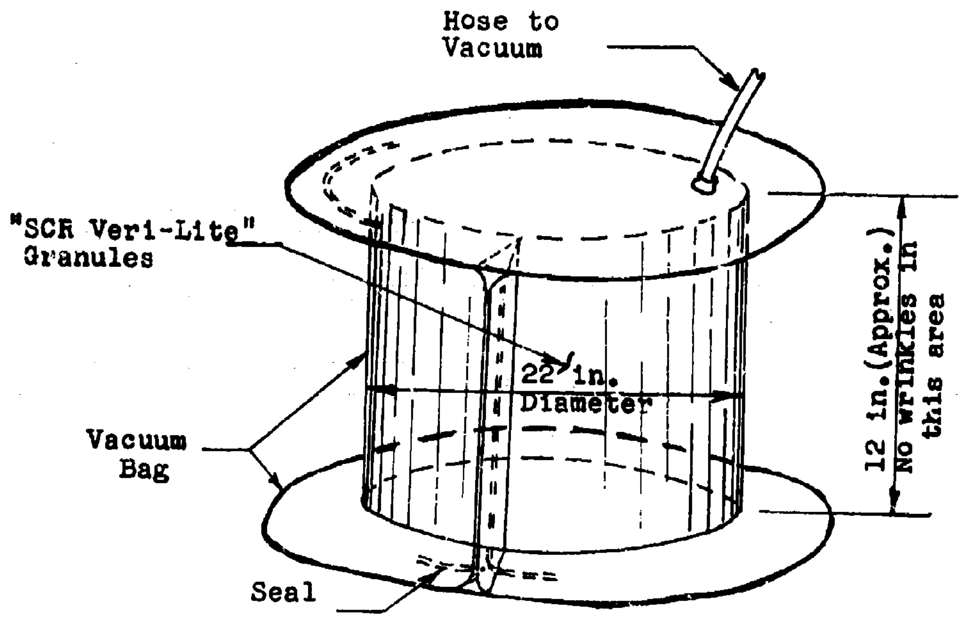


Figure 23 - "SCR Veri-Lite" Granule Compaction Test Set-Up

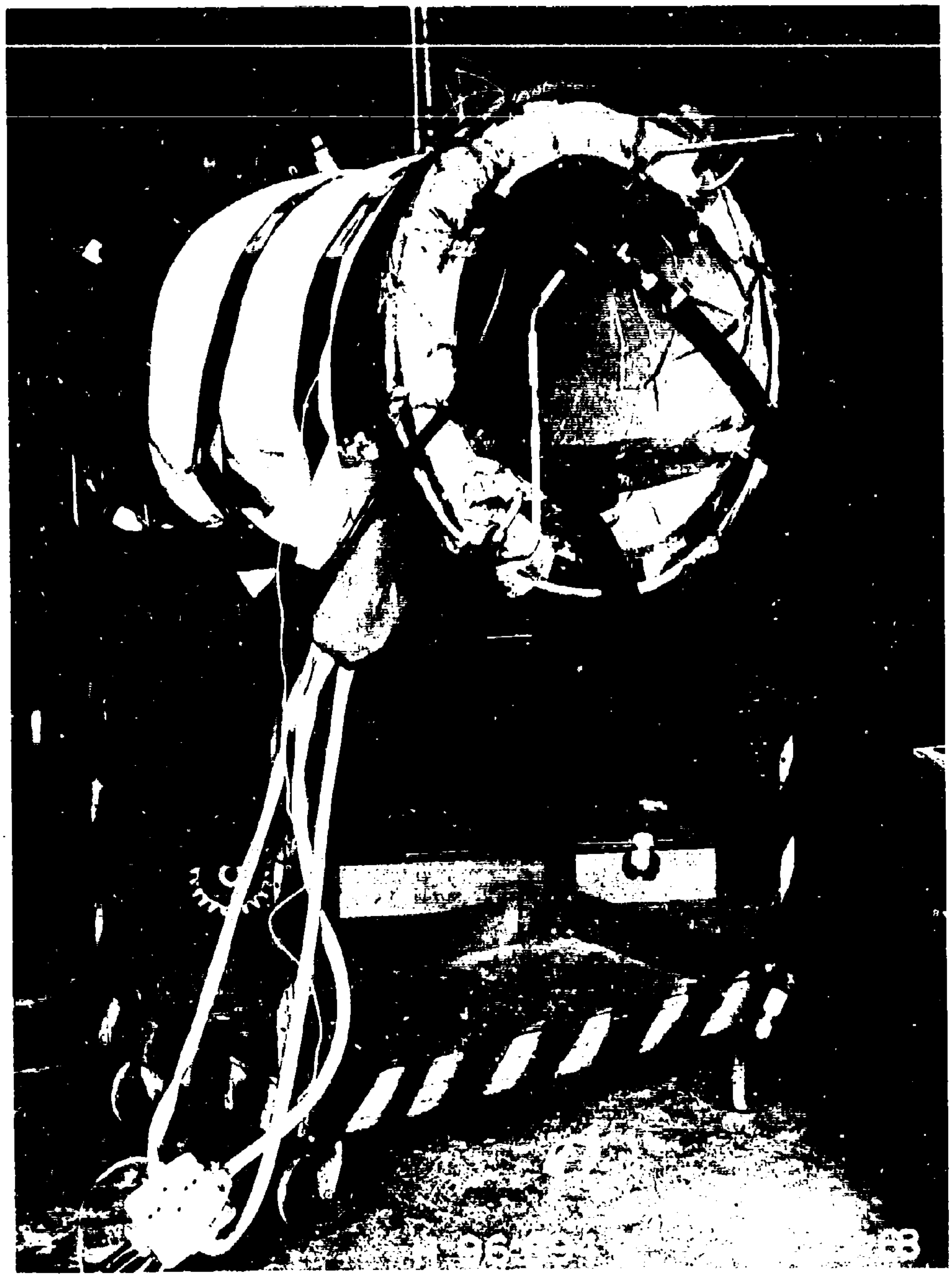
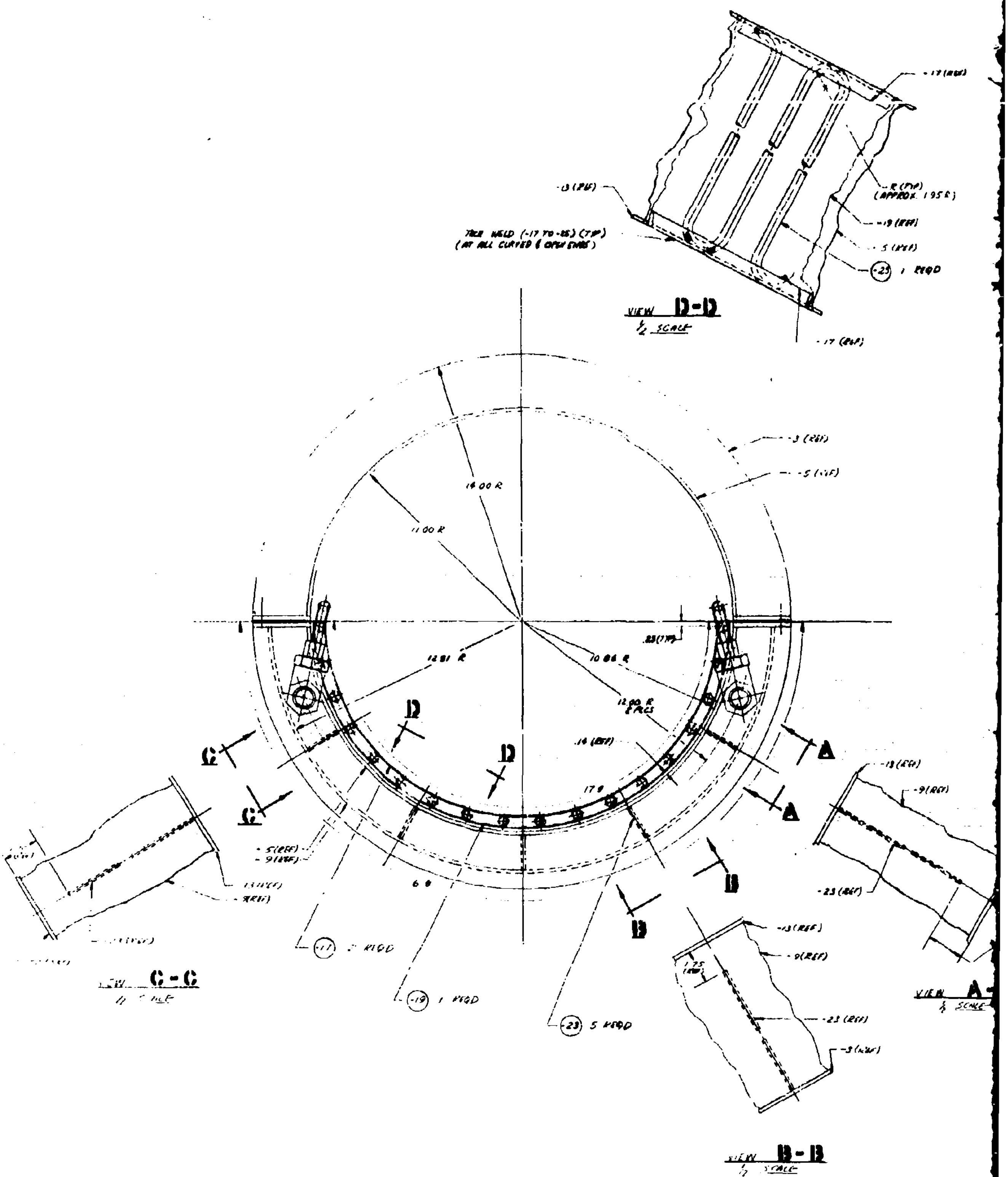
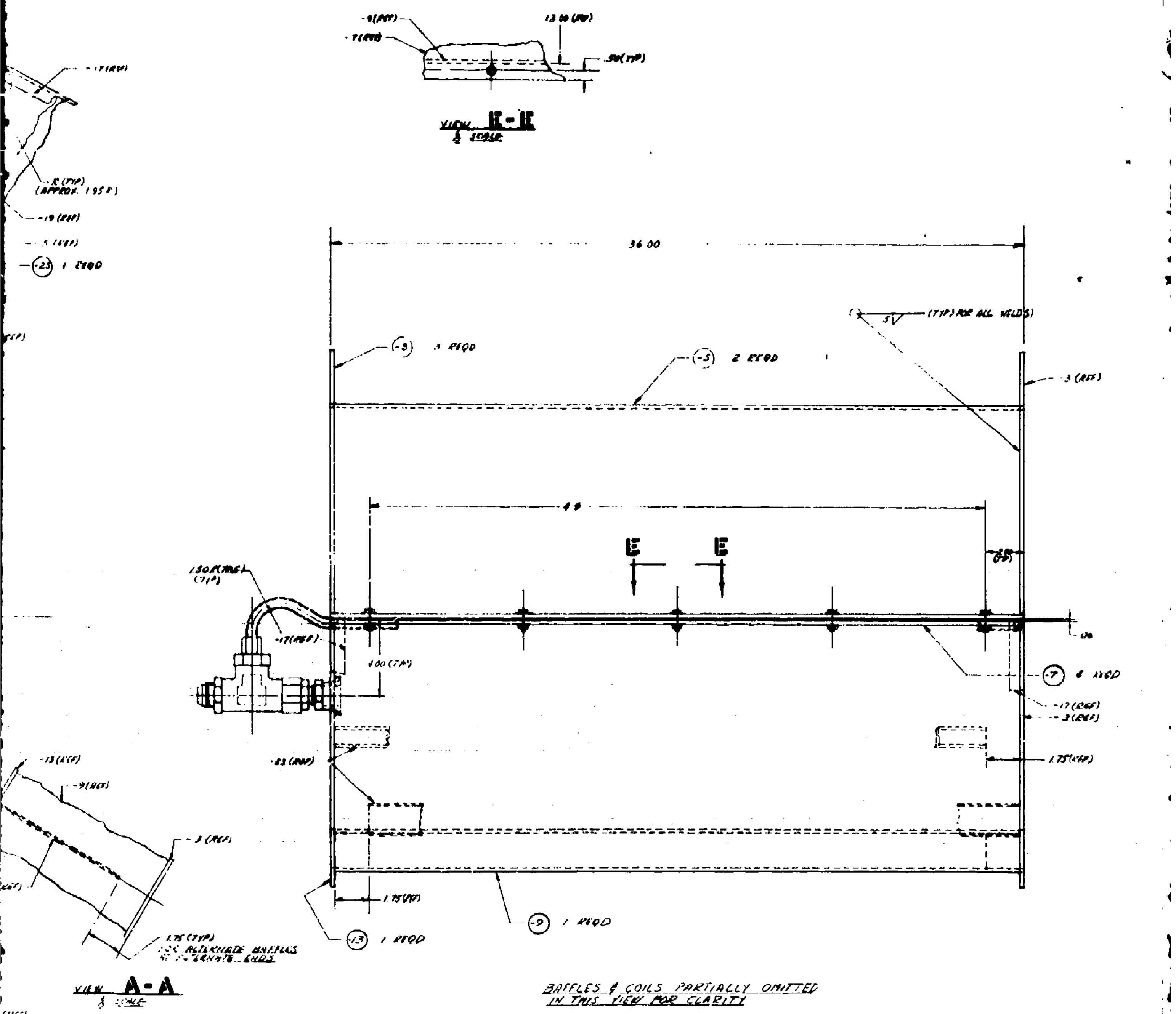


Figure 24 Electric Blanket Heat Application Set-up


VIEW D-D
1/2 SCALE
VIEW C-C
VIEW B-B
VIEW A
14.00 R
11.00 R
12.81 R
10.86 R
-23 1 REQD
-19 1 REQD
-23 5 REQD

A

16 15 14



BAFFLES & COILS PARTIALLY OMITTED
IN THIS VIEW FOR CLARITY

13 12 11 10 9

8	7	6	5	4

.3 (REF)

7 4 X ØD

.17 (REF)
.3 (REF)

.175 (REF)

2- SYMBOL 6 DENOTES EQUAL SPACES
1- ALL WELDS PER HA 0107-006 GRADE B
NOTES UNLESS OTHERWISE NOTED

APPLICATION (USA

8	7	6	5	4

5	4	3	2	1			

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
		1 NOW BE REWORKED 3 RECORD CHANGE 2 CANNOT BE REWORKED 4 NEW SHOP PRACTICE 5 PARTS MADE ON		

ITEM OR FIND NO	-21	-11	ASSY	CODE IDENT	PART OR IDENTIFYING NUMBER	NOMENCLATURE	MATERIAL	THICK GAUGE OD/ID	WIDTH	L.G.	DRAWING OR SPECIFICATION NUMBER	ZONE
037												
036												
035												
034												
033												
032	2				AN 871-12 D	FLANGE						
031			2			O RING						
030			2		MS 20819-8D	SLEEVE						
029			2		AN 818-8D	NUT						
028			2		AN 919-20 D	REDUCER						
027			2		AN 924-12 D	NUT						
026			2		AN 832-12 D	UNION						
025			2		AN 893-22D	BUSHING						
024			2		AN 815-16D	UNION						
023			2		AN 918-D16	TEE						
022												
021			20		LD153-0011-0016	WASHER						
020			10		AN 315-4R	NUT						
019			10		AN 4-11A	BOLT						
018												
017												
016												
015												
014			2		-27	SPACER	ASBESTOS FABRIC		3	36.00	MAL-30.12 TYPE VIII	
013			1		-25	TUBING	5052-O AL	.040	50.00	580FT	WW-T-700/4	
012	5				-23	BAFFLE	6061-T6 AL PL	19	1.62	3.187	QQ-A-250/11	
011			1		-21	SUB ASSY						
010			1		-19	LINER	6061-T6 AL SHT	.06	16.00	36.00	QQ-A-250/11	
009			1		-17	STRAP	6061-T6 AL SHT	.06	.75	35.00	QQ-A-250/11	
008												
007	1				-13	END	6061-T6 AL PL	19	4.00	28.00	QQ-A-250/11	
006			1		-11	SUB ASSY						
005	1				-9	SHELL	6061-T6 AL PL	19	42.00	36.00	QQ-A-250/11	
004	2	2			-7	PLATE	6061-T6 AL PL	19	3	36.00	QQ-A-250/11	
003		1			-5	SHELL	6061-T6 AL PL	19	36.00	36.00	QQ-A-250/11	
002	1	2			-3	END	6061-T6 AL PL	19	14.00	18.00	QQ-A-250/11	
001					TT-19557	ASSY OF						

QUANTITY REQUIRED — MATERIAL SIZE

PARTS LIST

APPLICATION (USAGE) DATA

HEAT TREAT

FINISH

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
UNDIMENSIONED DWG TOL ± .01 ANG ± 30'
DIMENSIONED DWG TOL .XX ± .03 ANGLE .XXX ± .010 ± 30'

INSPECT PER MIL-I-6870

DO NOT SCALE PRINT

CONTR NO
DR BY BILL EE 2/[illegible]
CHK BY
APPD

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION — COLUMBUS, OHIO 43216

CYLINDRICAL TOOL
(TEST SPECIMEN)

SIZE J — CODE IDENT NO 89372 — TT-19557

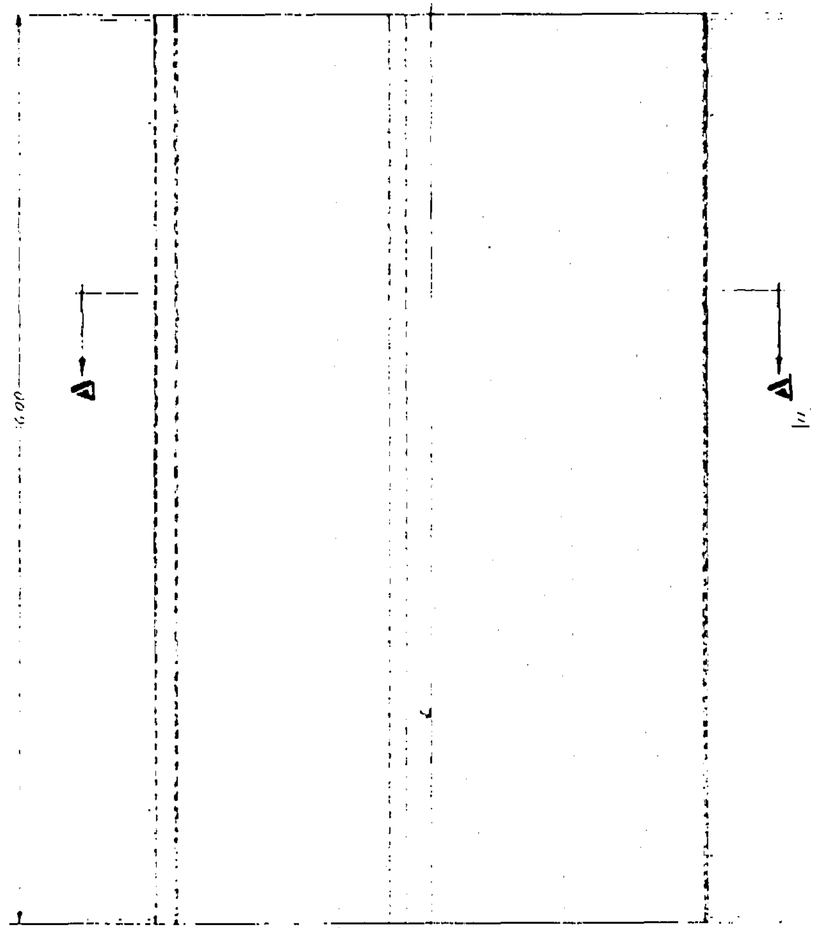
SCALE 1/2 — SHEET 1

TT 19557 1

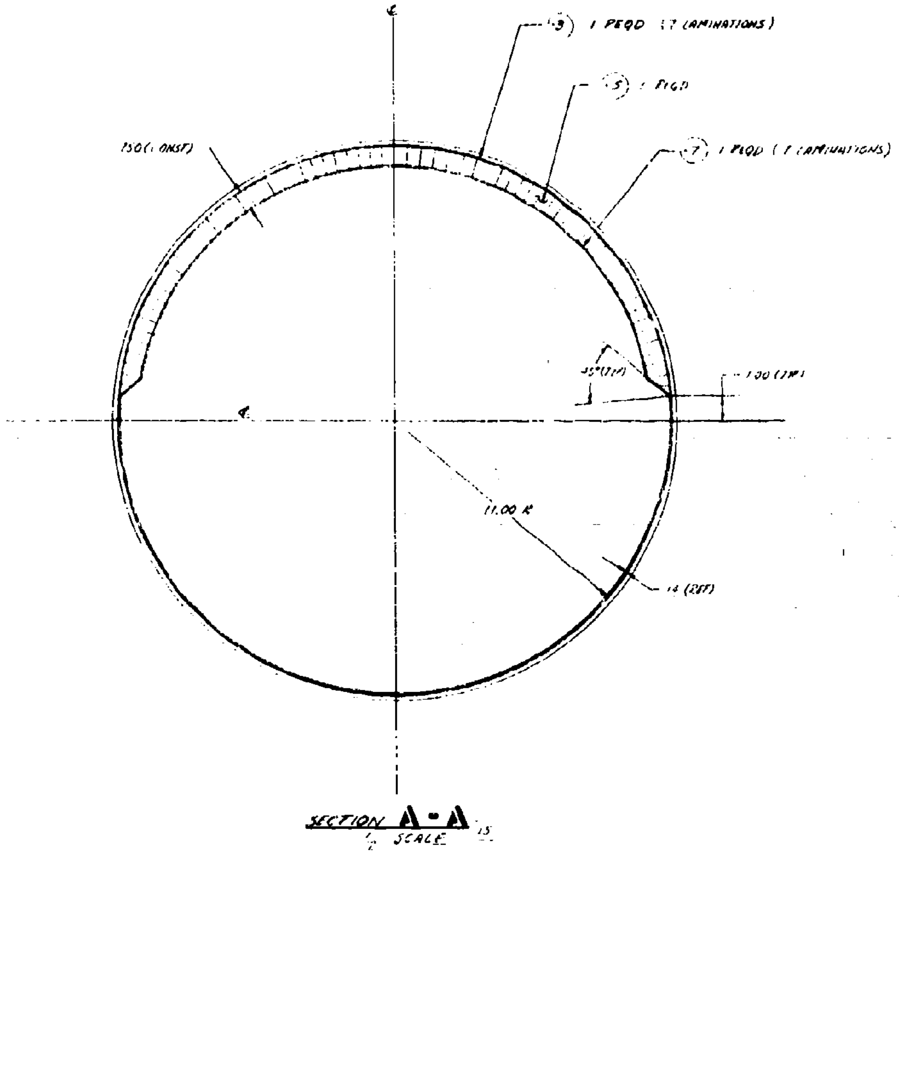
5	4	3	2	1

FORM 3114-2 REV 5-67

Figure 25 Cylindrical Tool - (Test Specimen)



NO INFORMATION
BEYOND THIS POINT
NOT FILMED



SECTION A-A
½ SCALE

7 6 5 4

NOTES UNLESS OTHERWISE NOTED

APPLICATION (USAGE) D

8 7 6 5 4

5	4	3	2	1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
		1 MAY BE REWORKED 3 RECORD CHANGE 2 CANNOT BE REWORKED 4 NEW SHOP PRACTICE 5 PARTS MADE ON		

D

PARTS LIST

ITEM OR FIND NO.	QUANTITY REQUIRED	CODE IDENT	PART OR IDENTIFYING NUMBER	NOMENCLATURE	MATERIAL	THICKNESS WIDTH GAGE OR DIA MATERIAL	LENGTH SIZE	DRAWING OR SPECIFICATION NUMBER	ZONE
037									
036									
035									
034									
033									
032									
031									
030									
029									
028									
027									
026									
025									
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017									
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015									
014									
013									
012									
011									
010									
009									
008									
007									
006									
005									
004	1		-7	FACE SHEET	MONSANTO GLASS FABRIC	.01	1.25 SQ FT		
003	1		-5	CORE	FLEXIBLE 5052 [illegible] HEX CORE	.750	16.00 DIA	[illegible]	
002	1		-3	FACE SHEET	MONSANTO GLASS FABRIC	.01	1.25 SQ FT		
001			TT-119557	ASSY OF					

APPLICATION (USAGE) DATA			
NEXT ASSY	USED ON		

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DO NOT SCALE PRINT

CONTR NO

DR BY [illegible] 2/1/[illegible]

CHK BY

APP

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION COLUMBUS, OHIO 43216

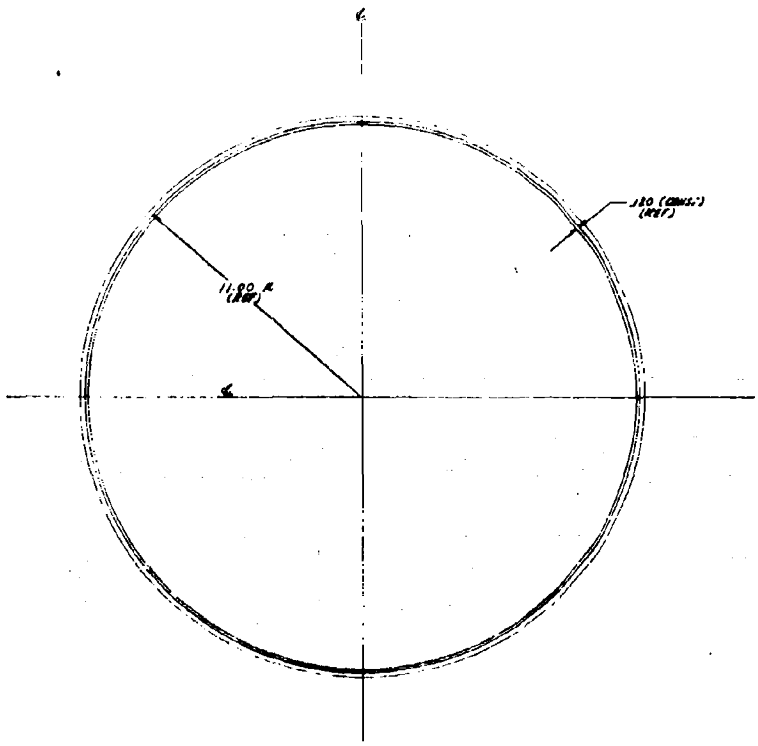
Cylindrical Part #1
(Test Specimen)

SIZE	CODE IDENT NO	
J	89372	TT 119557

SCALE 1/2 SHEET 1

FORM 311-G2 REV 5-67

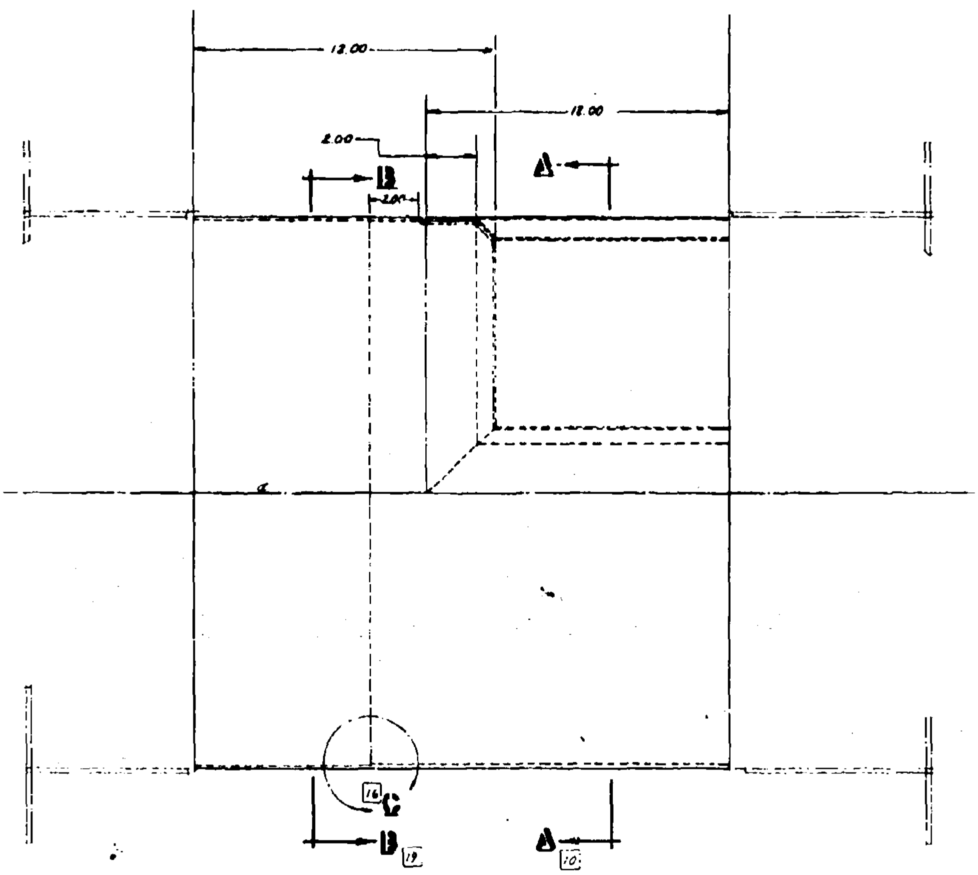
Cylindrical Part #1 - (Test Specimen)

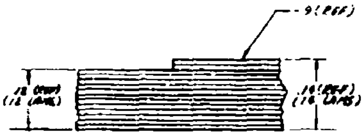


SECTION 13 - 13
1/4 SCALE 16

21 20 19 18 17

A



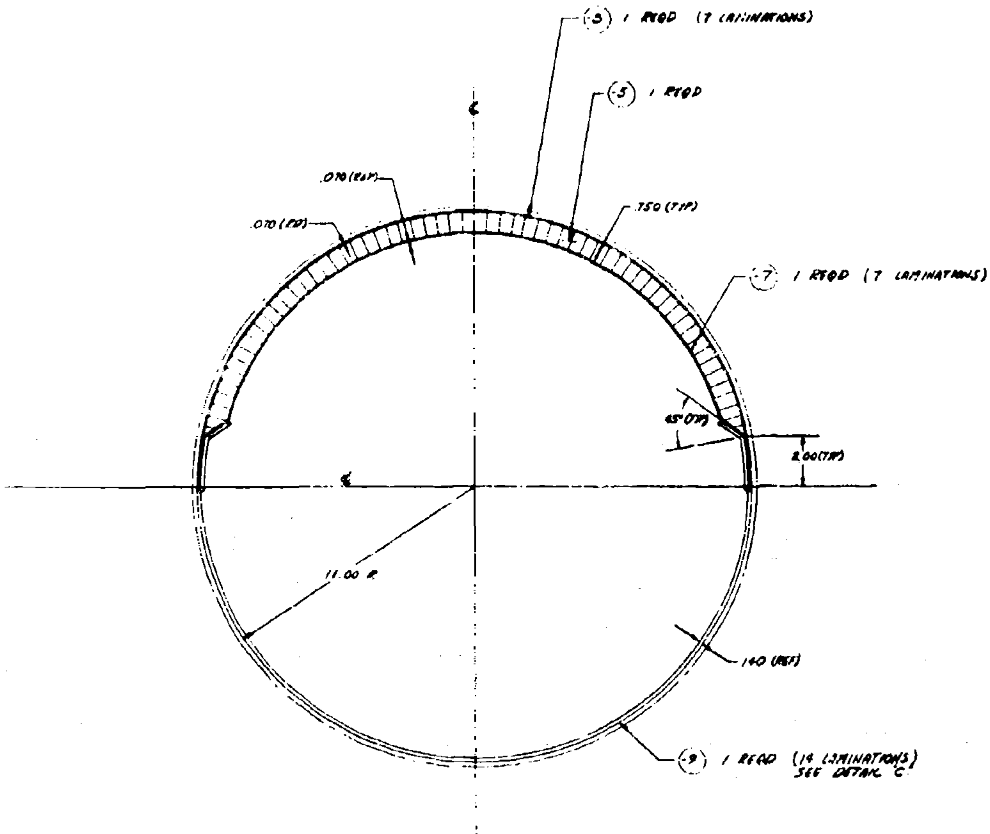


DETAIL C 15

SCALE

B

17 16 15 14 13 12



SECTION A-A (14)
1/2 SCALE

C

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ITEM OR FIND NO — QUANTITY REQUIRED — CODE IDENT

1

NOTES: UNLESS OTHERWISE NOTED

APPLICATION (USAGE) DATA

DO NOT SCALE

7	6	5	4	3

E

Item or Find No	Quantity Required	Code Ident	Part or Identifying Number	Nomenclature	Material	Thick Gauge	Width OD/D	LG	Drawing or Specification Number
005	1		-9	SKIN	MONSANTO GLASS FABRIC	.01	162.00 SQFT		
004	1		-7	FACE SHEET	MONSANTO GLASS FABRIC	.01	162.00 SQFT		
003	1		-5	CORE	FLEXIBLE 5052 AL ALY CORE	.750	[illegible]	36.00	ST 0170 -HB 0035
002	1		-3	FACE SHEET	MONSANTO GLASS FABRIC				
001			TT 129557	ASSY OF					

PARTS LIST

APPLICATION (USAGE) DATA

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DO NOT SCALE PRINT

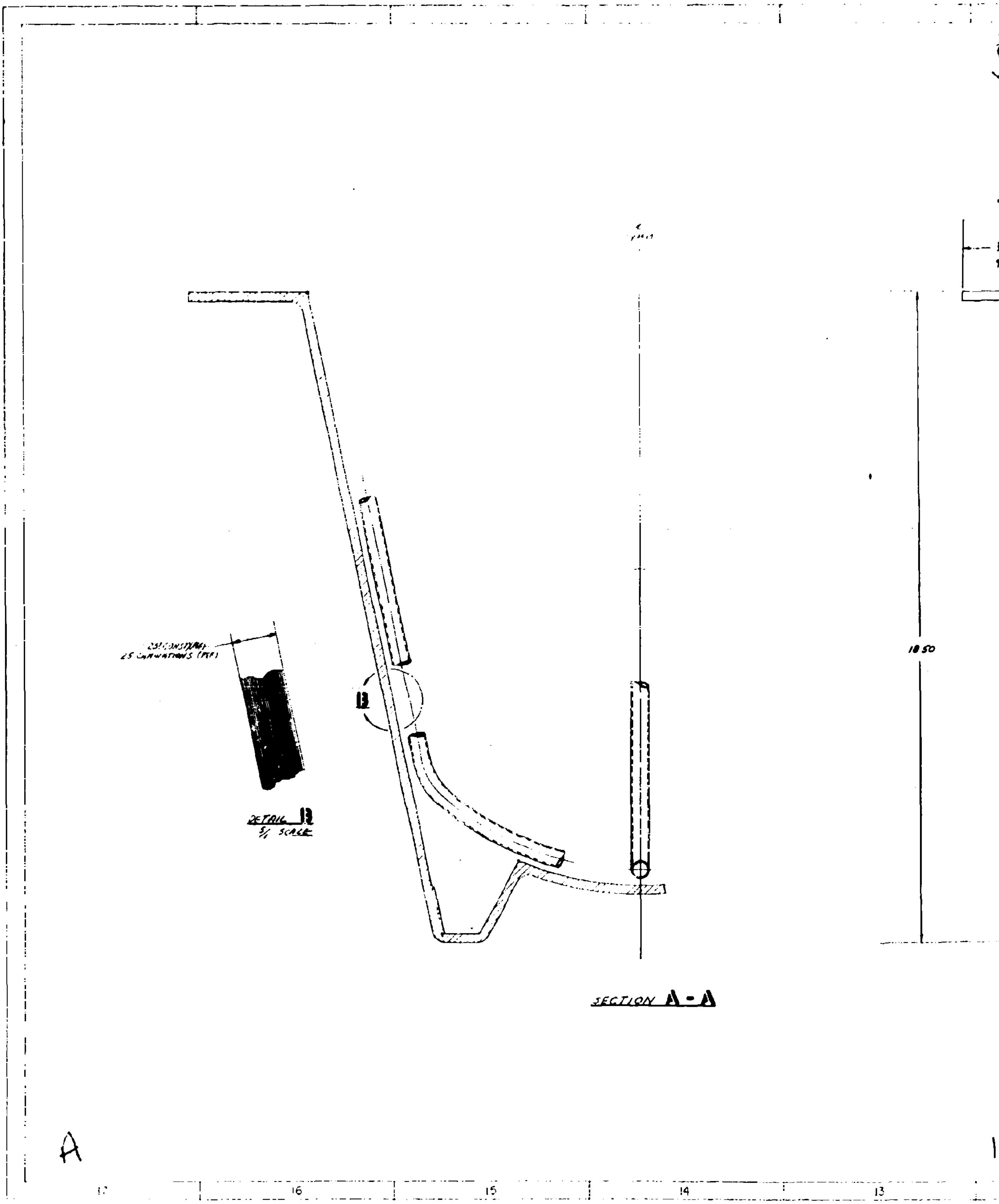
NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION COLUMBUS, OHIO 43216

CYLINDRICAL PART #2
(TEST SPECIMEN)

J 89372 TT-129557

SHEET 1

Figure 27 Cylindrical Part #2 - (Test Specimen)



DETAIL B
5/1 SCALE
B
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SECTION A - A
A
16
15
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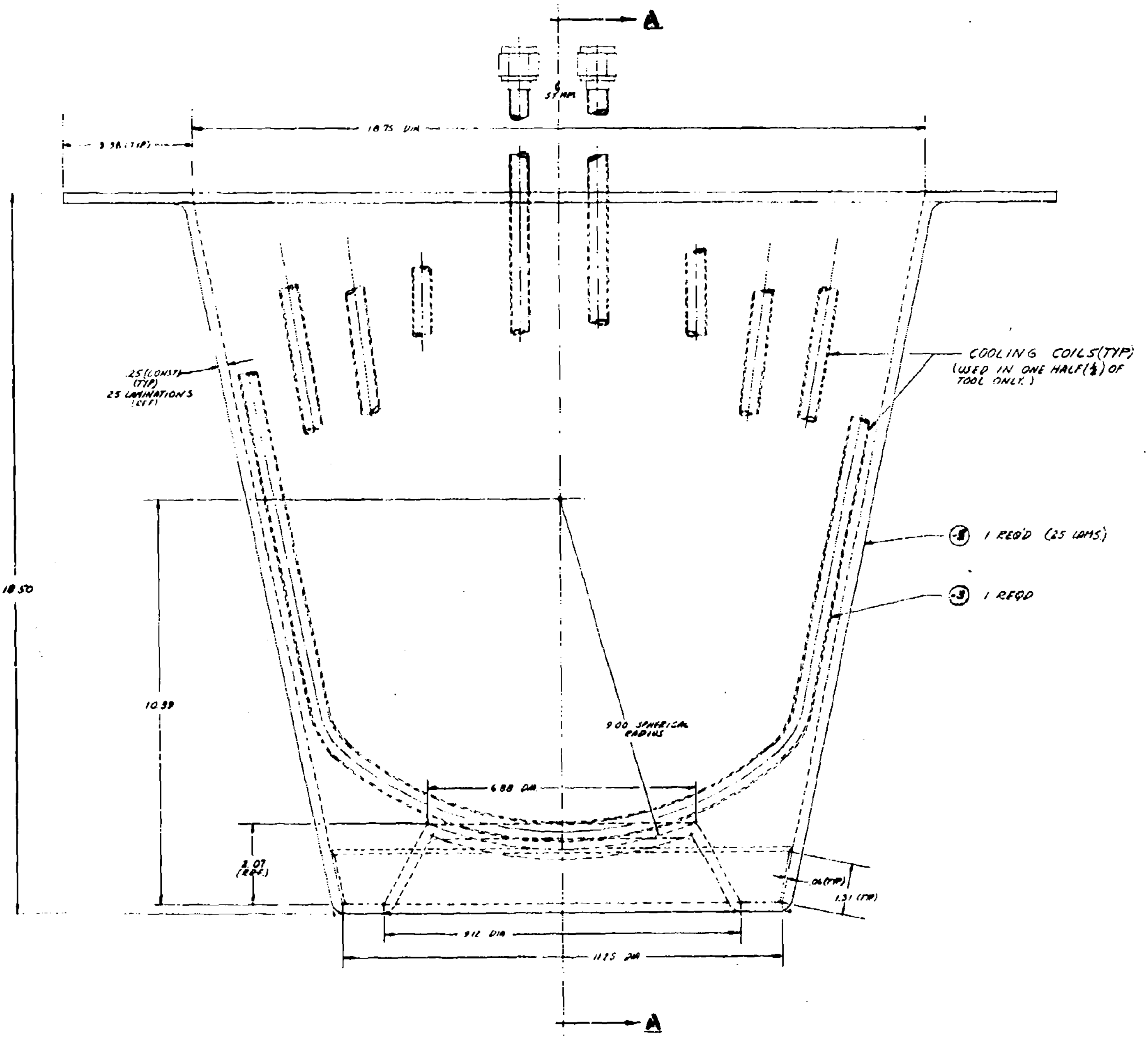
13



A
18.75 DIA
.25 (CONST) (TYP) 25 LAMINATIONS (REF)
COOLING COILS (TYP) (USED IN ONE HALF (½) OF TOOL ONLY.)
1 REQ'D (25 LAMS.)
1 REQD
18.50
10.39
9.00 SPHERICAL RADIUS
6.88 DIA
2.07 (REF)
.06 (TYP)
1.31 (TYP)
9.12 DIA
11.25 DIA
A

12
11
10
9
8

7	6	5	4	3

NG COILS(TYP)
ONE HALF(½) OF

OD (25 LAMS.)

OD

NOTES. UNLESS OTHERWISE NOTED

APPLICATION (USAGE) DATA

QUAN'TY REQUIRED

7	6	5	4	3

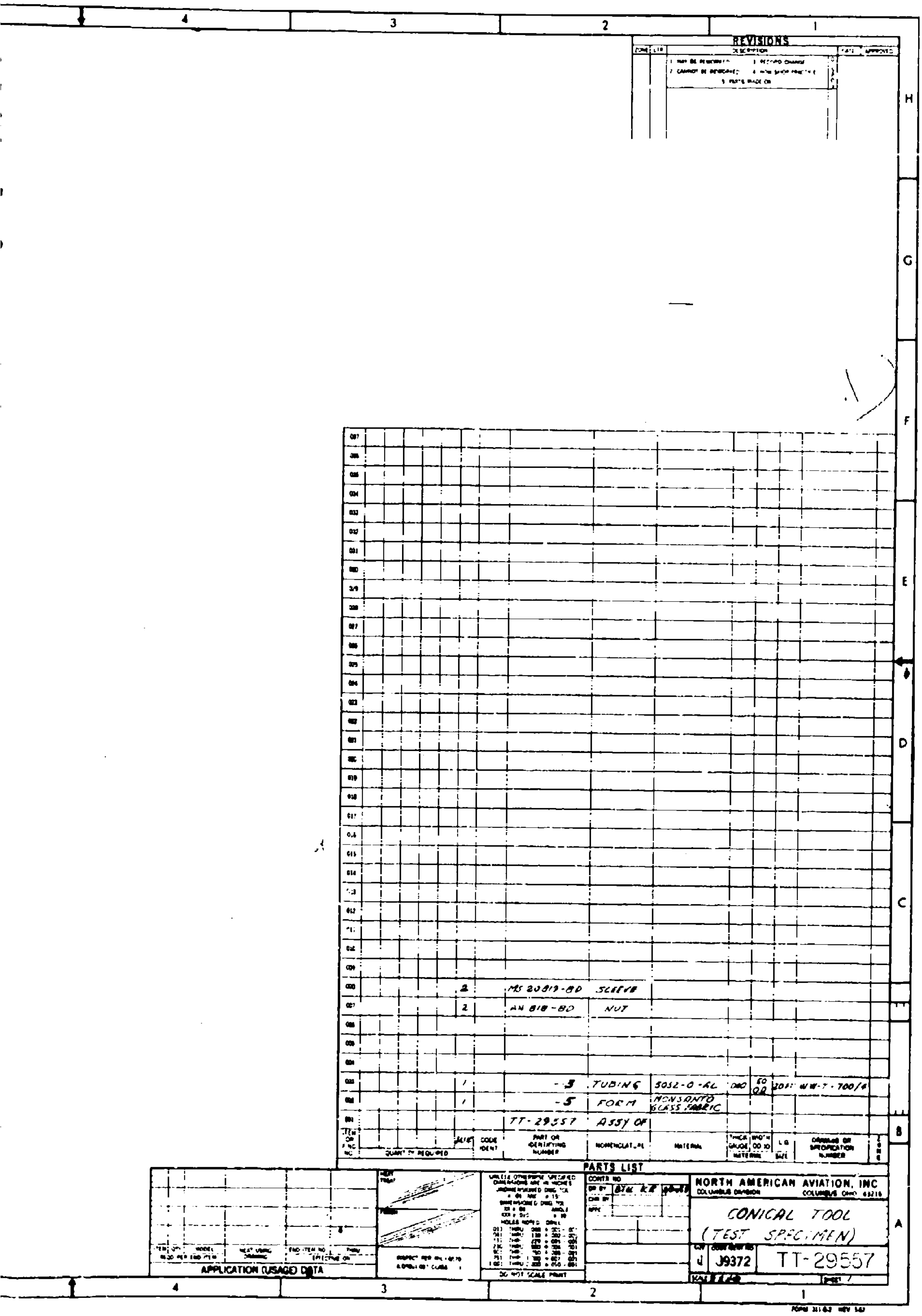
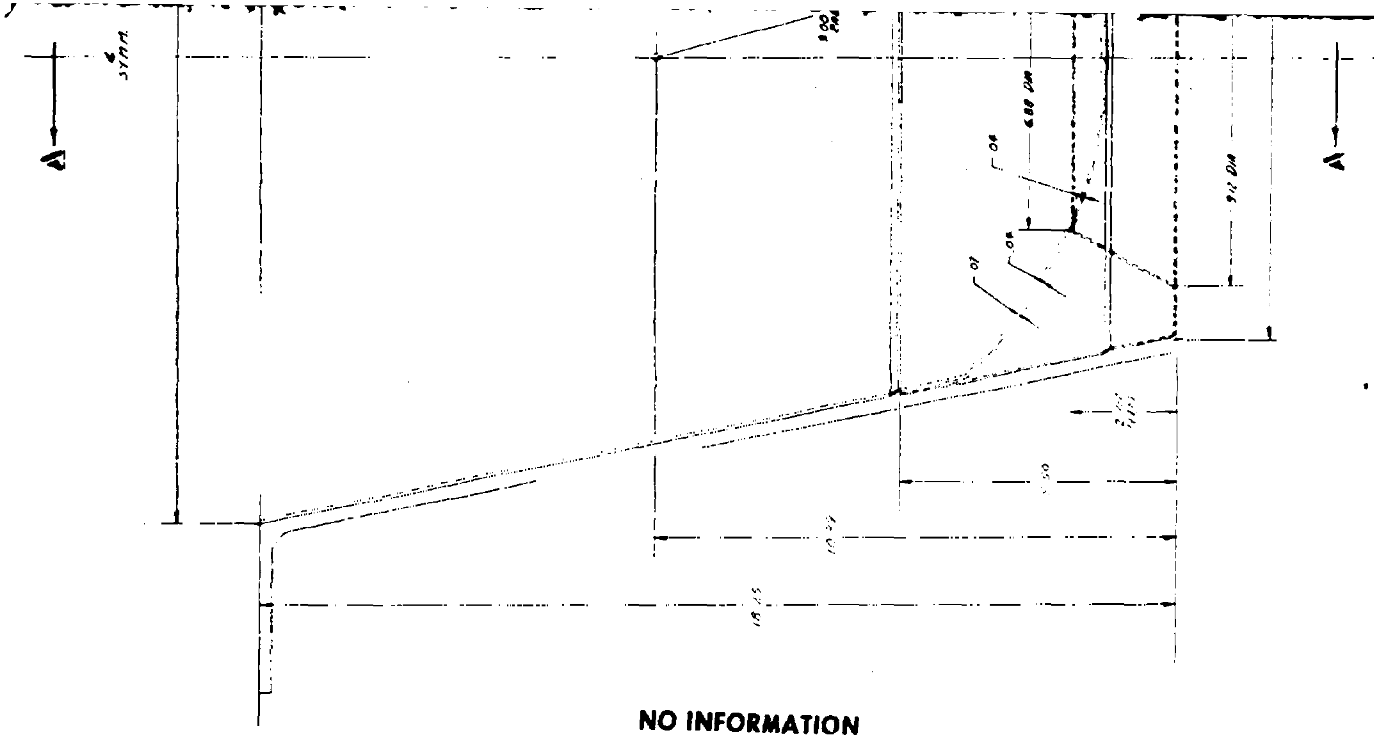
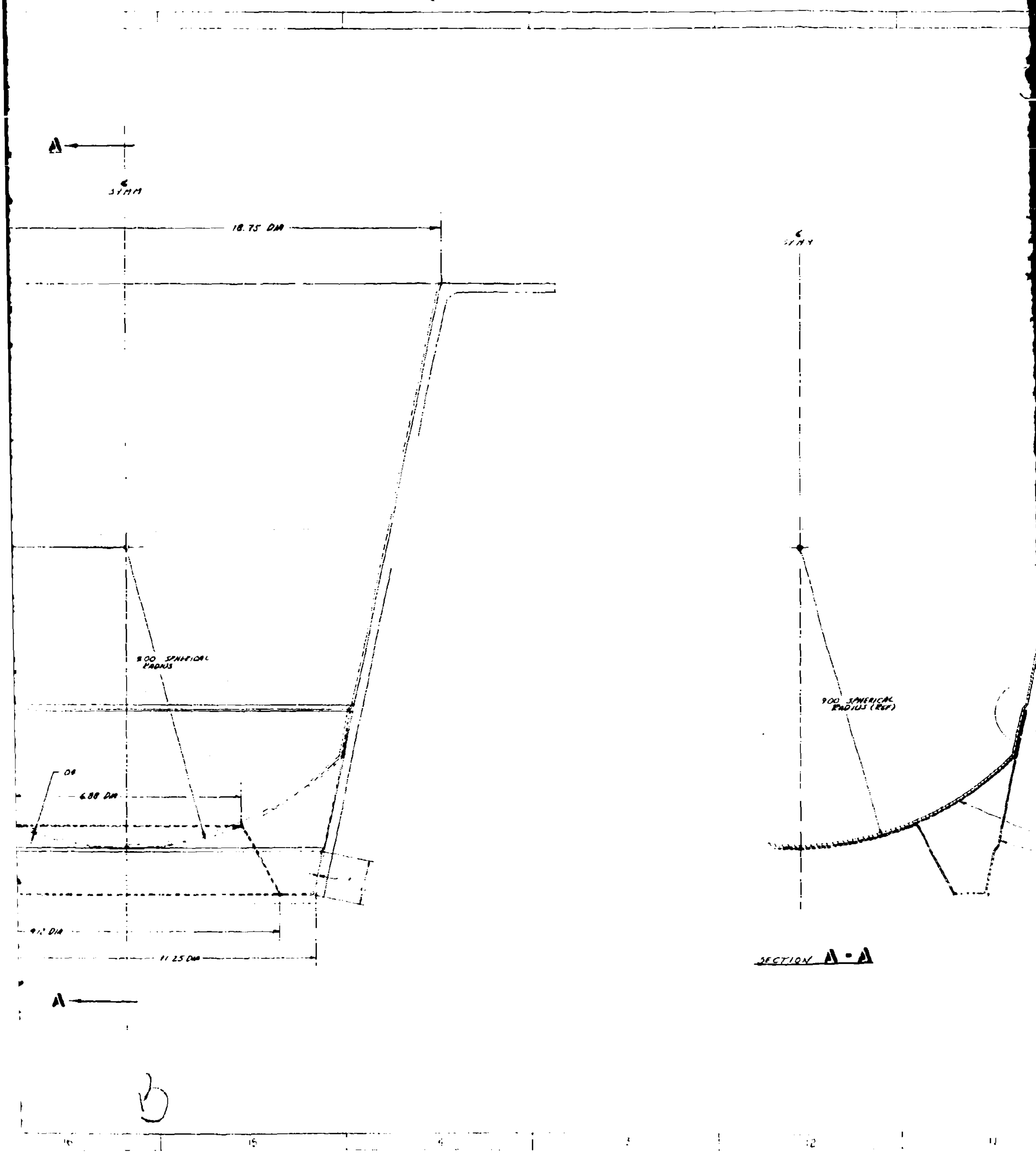


Figure 28 Conical Tool - (Test Specimen)

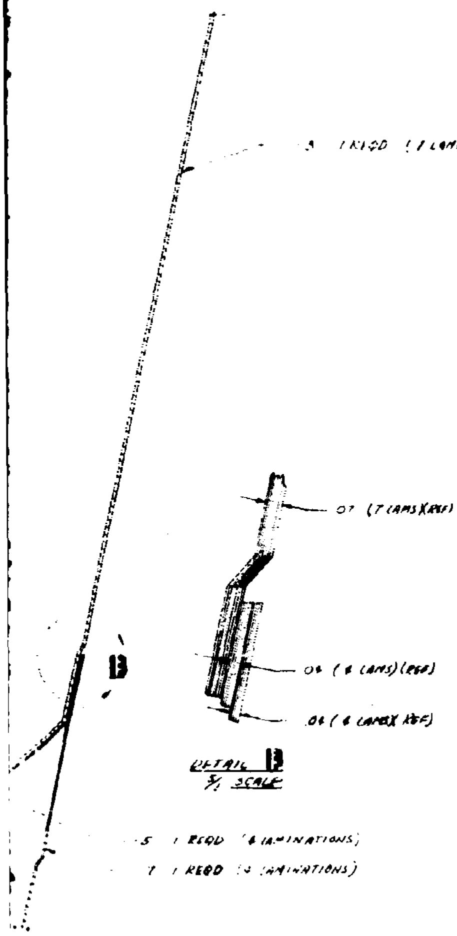


NO INFORMATION
BEYOND THIS POINT
NOT FILMED


A
SYMM
18.75 DIA
SYMM
9.00 SPHERICAL RADIUS
6.88 DIA
11.25 DIA
A
9.00 SPHERICAL RADIUS (REF)

SECTION A - A

7	6



DETAIL B
5/1 SCALE

-5 1 REQD (4 LAMINATIONS)
-7 1 REQD (4 LAMINATIONS)

NOTES: UNLESS OTHERWISE NOTED

8	7	6

Item or Find No	Quantity Required	Code Ident	Part or Identifying Number	Nomenclature	Material	Thick Width Gauge Code Material	LG Size	Drawing or Specification Number	Zone
037									
036									
035									
034									
033									
032									
031									
030									
029									
028									
027									
026									
025									
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013									
012									
011									
010									
009									
008									
007									
006									
005									
004	1		-7	CAP	MONSANTO GLASS FABRIC				
003	1		-5	DOUBLER	MONSANTO GLASS FABRIC				
002	1		-3	BODY	MONSANTO GLASS FABRIC				
001			TT-219557	ASSY OF					

PARTS LIST

APPLICATION (USAGE) DATA

DO NOT SCALE PRINT

DR BY Bell E R 2/23/66

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION COLUMBUS, OHIO

CONICAL PART #1 & #2
(TEST SPECIMEN)

SIZE	CODE IDENT NO	
J	89372	TT-219557

SCALE FULL SHEET 1

FORM 311-G-2 REV 5-63

Figure 30 Precured Partial Hardback of "Saddle-type" Concept c.(2)

Figure 31 Collapsed Cylindrical Test Specimen, c.(2)

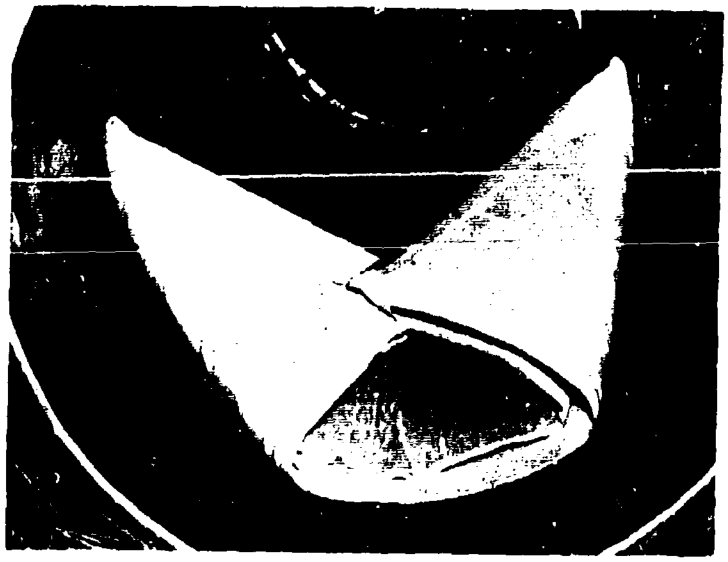


Figure 32 Further Collapsing of B-staged Portion, c.(2)

Figure 33 Rigidized Cylindrical Test Specimen of "Saddle-type" Concept, c.(2)

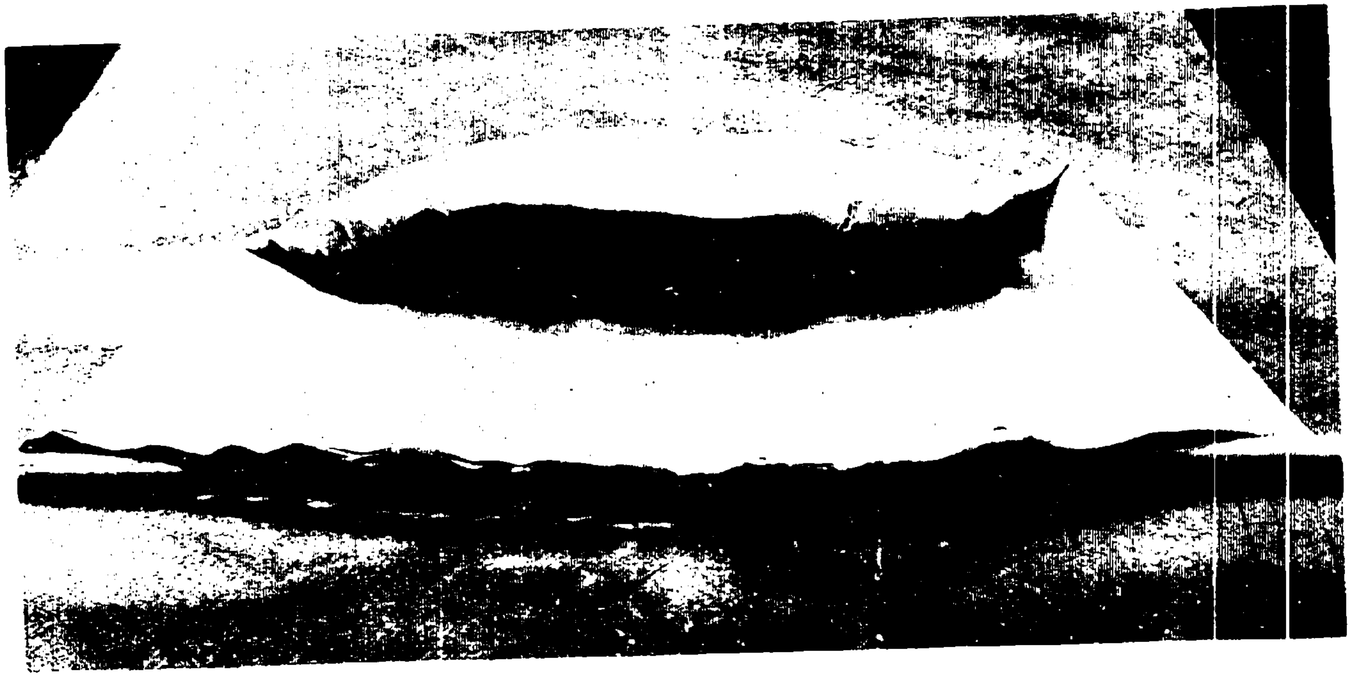


Figure 34 Collapsed Conical Test Specimen of "Saddle-type" Concept, c.(4)

Figure 35 Expanded Conical Test Specimen, c.(4)

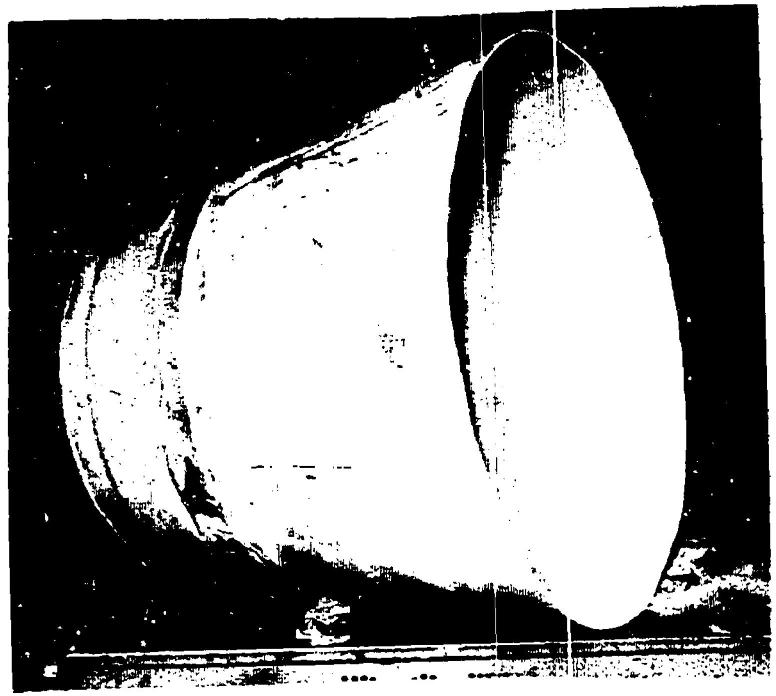


Figure 36 Rigidized Conical Test Specimen, c.(4)

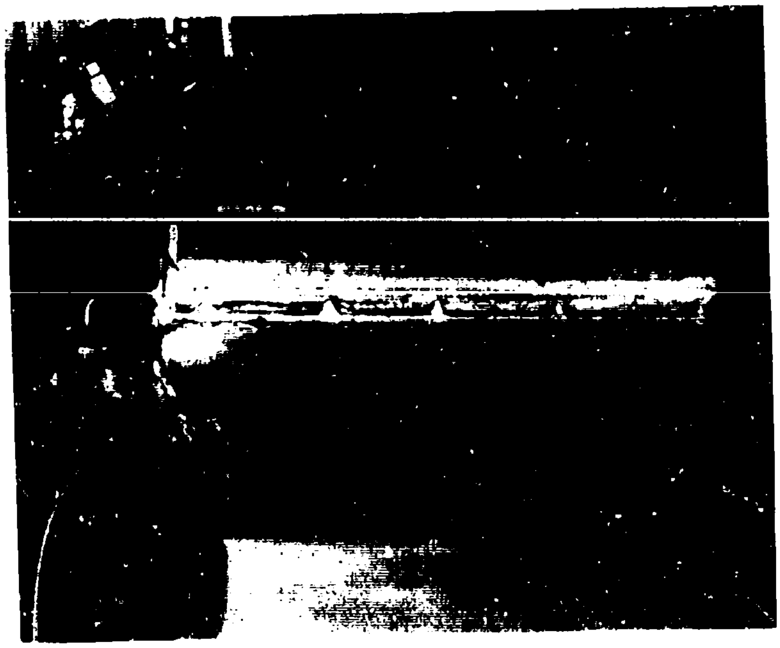


Figure 37 Tool for Cylindrical Test Specimens

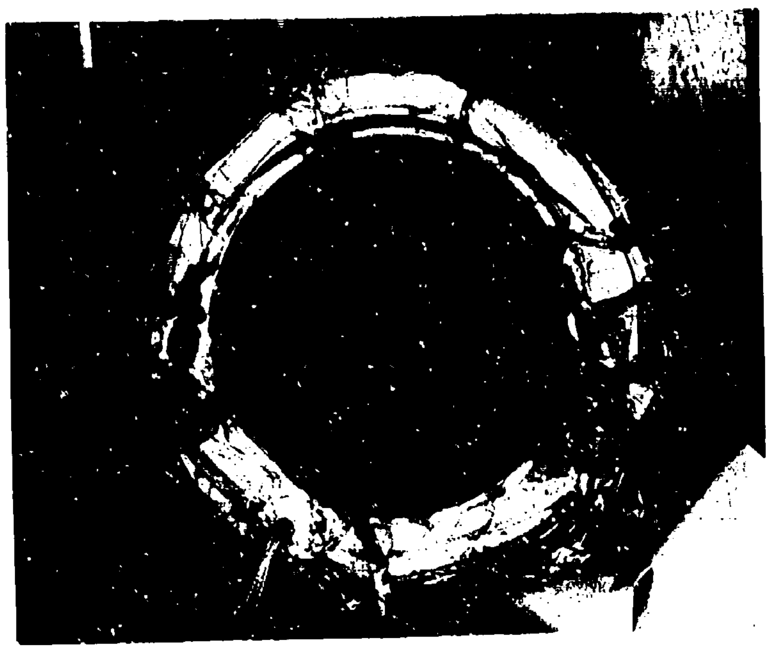


Figure 38 Vacuum-bagged Cylindrical Test Specimen, c.(1)

Figure 39 Collapsed Cylindrical Test Specimen, c.(1)

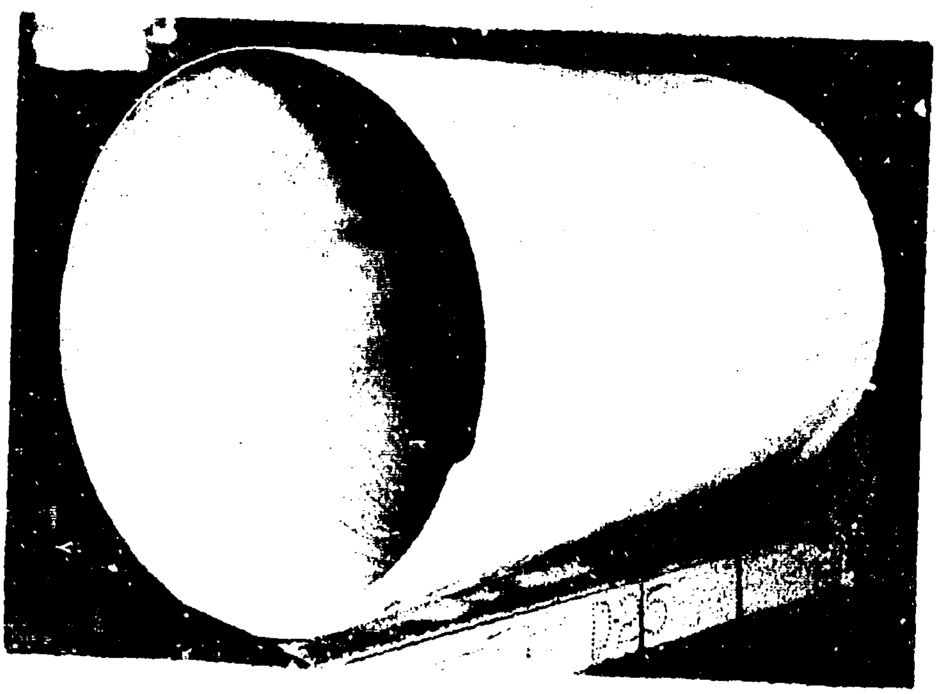


Figure 40 Rigidized Cylindrical Test Specimen, c.(1)

Figure 41 Tool for Conical Test Specimens

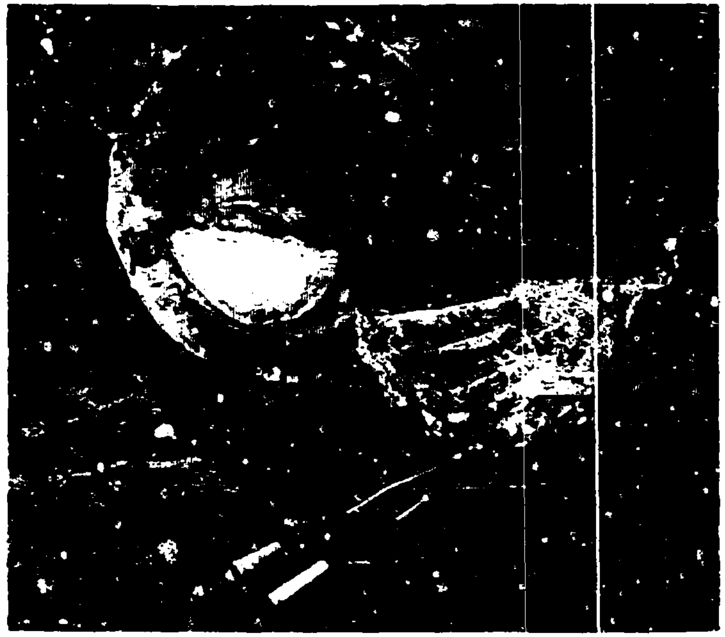


Figure 42 Partial Cured Conical Test Specimen c.(2)

Figure 43 Collapsed Conical Test Specimen c.(3)

Figure 44 Expanded Conical Test Specimen c.(3)

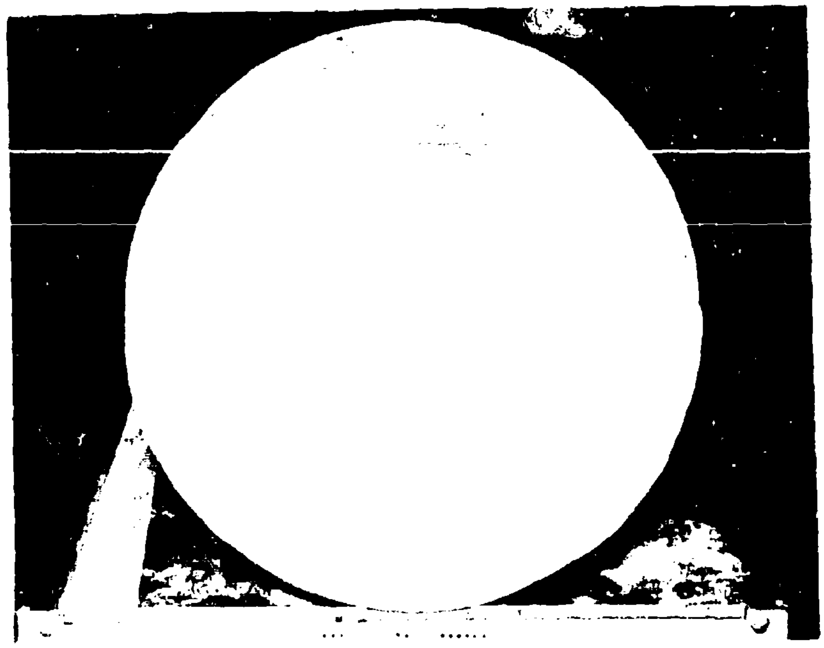


Figure 45 Rigidized Conical Test Specimen c.(3)

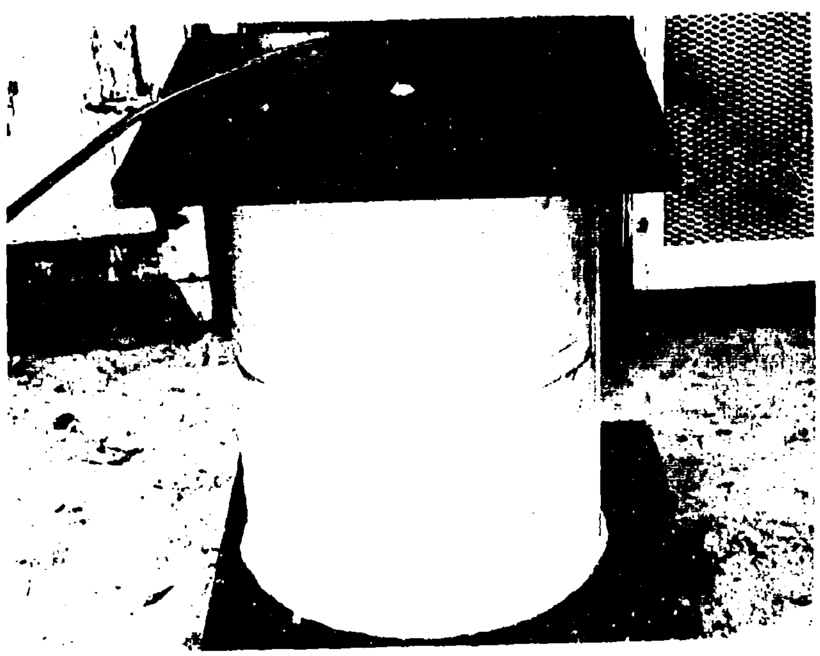


Figure 46 Vacuum Burst Test Set-up

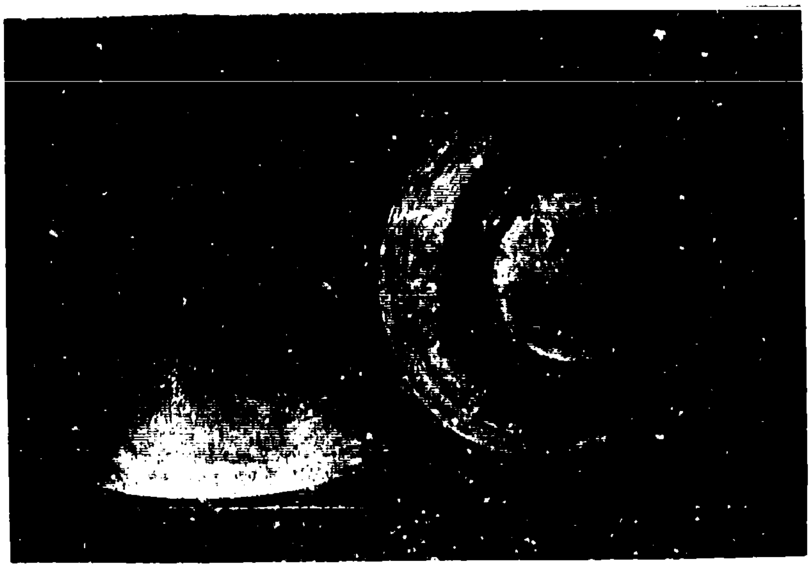


Figure 47 Inside View of Bolting Ring and Cap

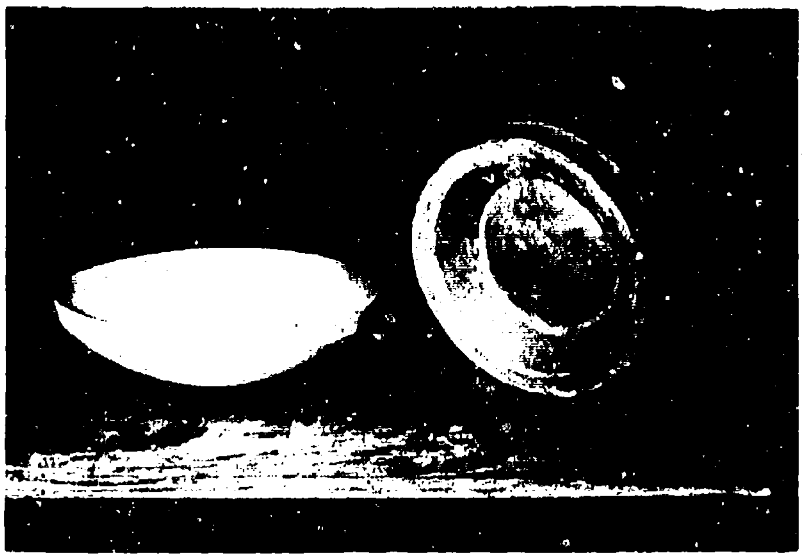
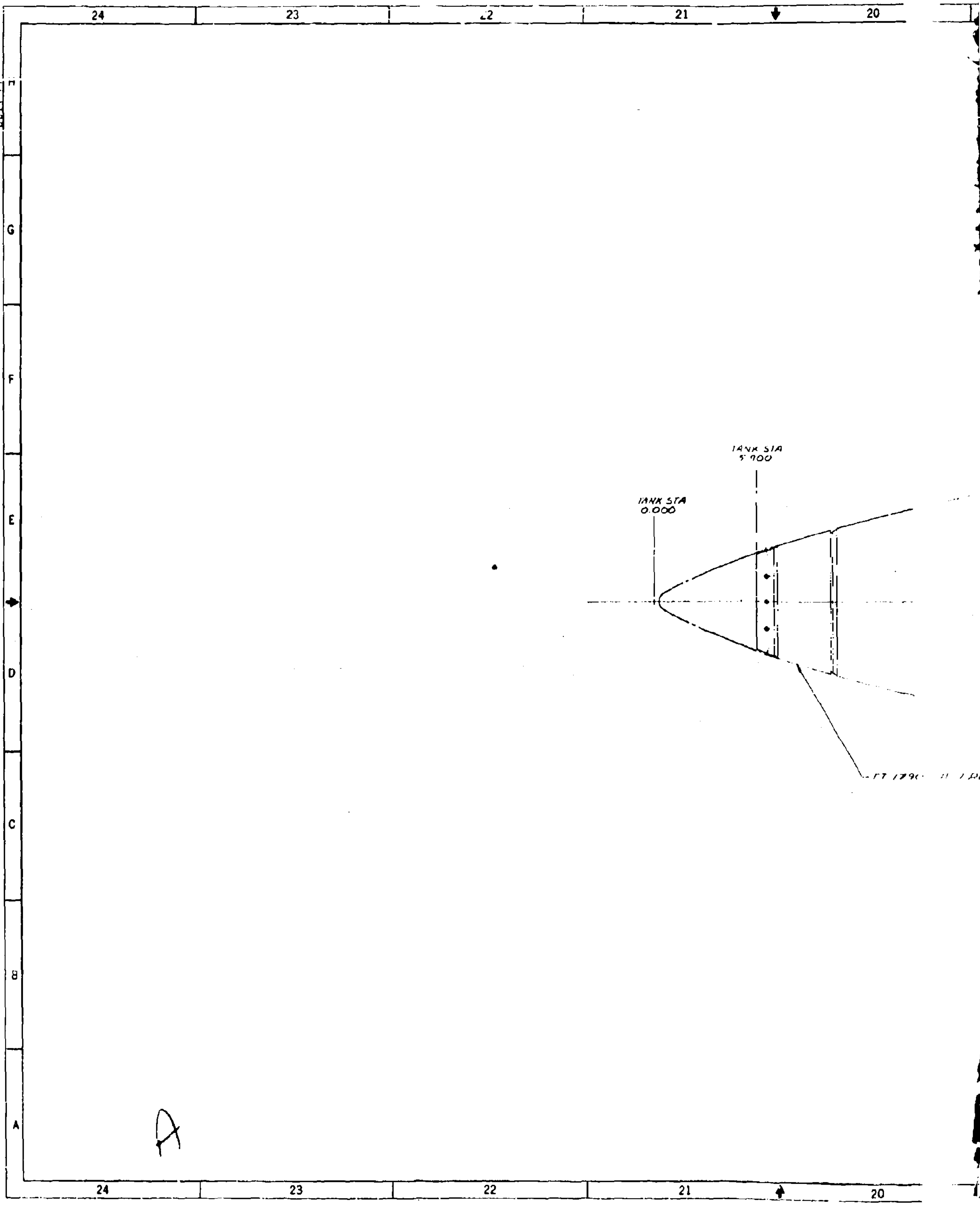
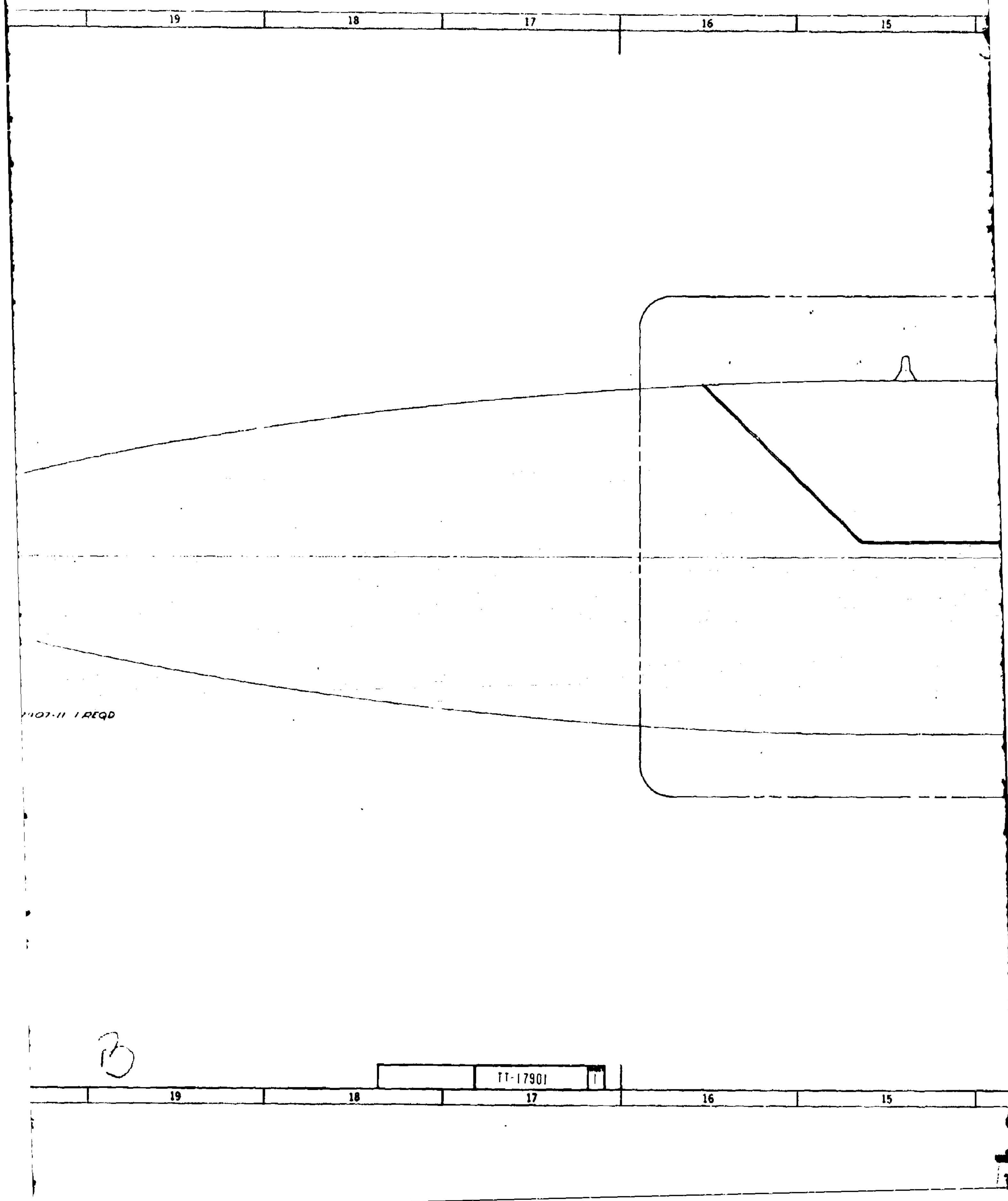
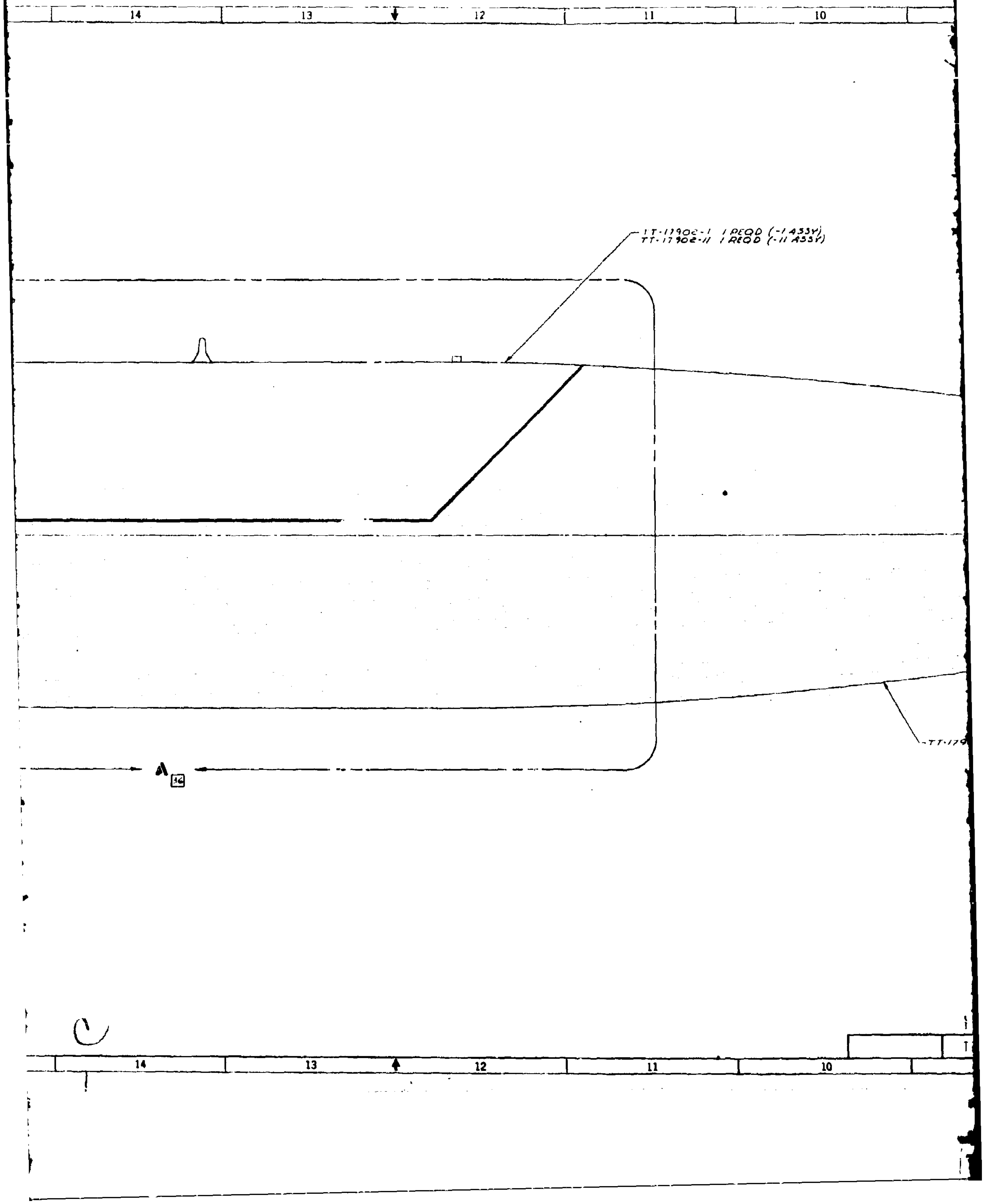
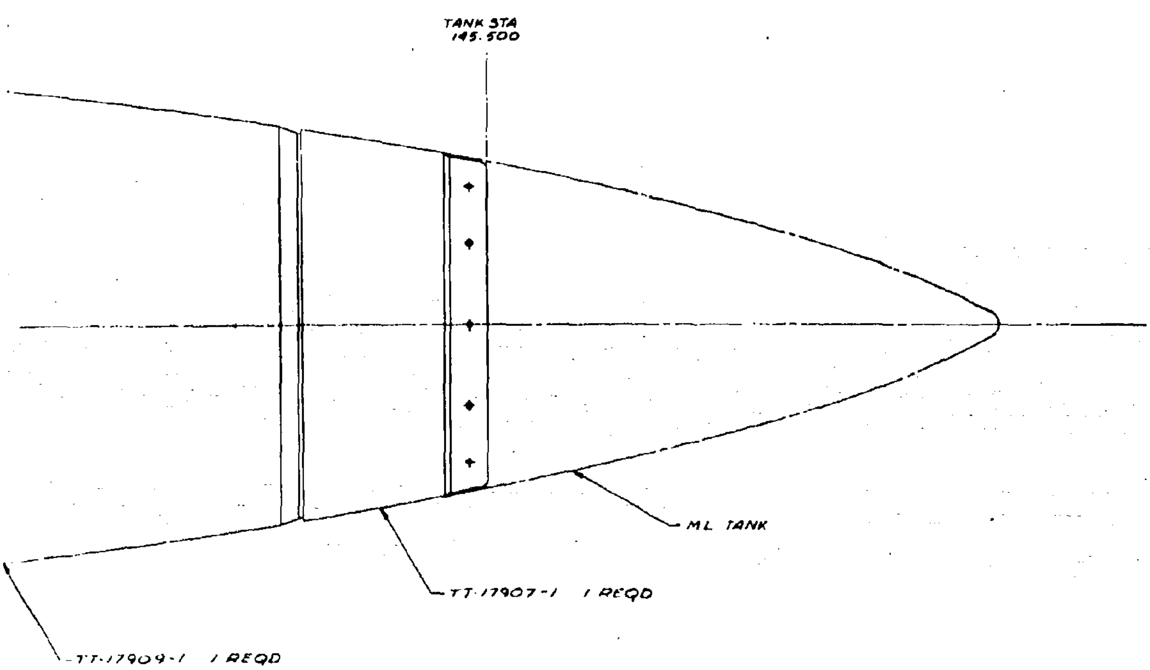


Figure 48 Outside View of Bolting Ring and Cap


24
23
22
21
20
H
G
F
E
D
C
B
A
TANK STA
5 900
TANK STA
0.000
A


19
18
17
16
15
907-11 1 REQD
TT-17901
1
19
18
17
16
15


14
13
12
11
10
TT-17902-1 1 REQD (-1 ASSY)
TT-17902-11 1 REQD (-11 ASSY)
TT-179
A
14
13
12
11
10



(2) 9. VENDOR ITEM SEE SPEC CONTROL DWG
8. SYMBOL $ DENOTES EQUAL SPACES.
7. AIR CONNECTION LOCATED AT STA 94.60 IS TAPPED FOR A 1/4" NIPPLE. FLUID DRAIN CONNECTION LOCATED AT STA 99.00 IS TAPPED FOR A 1/2" NIPPLE.
(1) 6. GOVERNMENT FURNISHED AIRCRAFT EQUIPMENT. (GFAE)
(A2) 5 IDENTIFY PER NR SPEC ST0605HA0012
(A1)
3. INSTALL THREADED FASTENERS PER NR SPEC LA0101-001.
2. FOR BEVELS & CONTOURS SEE MD NOR 62-82.
1. FABRICATE PER NR SPEC ST0605HA0012
NOTES: UNLESS OTHERWISE NOTED

TT-17901

9	8	7	6	5

5	4	3	2	1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
		1 MAY BE REWORKED 3 RECORD CHANGE 2 CANNOT BE REWORKED 4 NON SHOP PRACTICE 5 PARTS MADE OK		
		(WAS) BOND TT 17907-1 & -11 TO TT 17909-1 WITH EC 2216 PER NR SPEC NA 0105-055		
		2-IDENTIFY PER NR SPEC ... HA 0... (WAS) IDENTIFY PER NR SPEC LA 0108-003 EXCEPT ... HOT METAL IMPRESSION STAMP		

ITEM OR FIND NO	QUANTITY REQUIRED				-11	-1	CODE IDENT	PART OR IDENTIFYING NUMBER	NOMENCLATURE	MATERIAL	THICK GAGE	WIDTH DIA	LG	DRAWING OR SPECIFICATION NUMBER	ZONE
037															
036															
035															
034															
033															
032															
031															
030					2	2		NAS1598-3Y	SEALING WASHER						34
029					24	24		NAS1154-16	SCREW						47
028					152	152		NAS1154-14	SCREW						38,
027					2	2		NAS1134-3	SCREW						34
026															
025					24	24		MS29513-010	"O" RING						47
024					2	2		MS21042L3	NUT						34
023					1	1		MS20913-4S	PLUG						33
022															
021					1	1		AN737TW30	CLAMP						32
020															
(1) 019					1	1		SP4348287	RETAINER						34
(1) 018						2		6-52834-1	LUG						38
(1) 017					1	1		3-116104-1	DRAIN						34
016															
(2) 015					152	152		HE114-0032-0008	NUTPLATE						38, 47
014					1	1		3H2L-8-81	HOSE						33
013															
012					1	1		TT-17909-1	TANK						9
011					1	1		TT-17907-11	BOLTING RING						20
010					1	1		TT-17907-1	BOLTING RING						8
009					2	2		TT-17904-4	CLIP						44
008					2	2		TT-17904-3	CLIP						44
007					2	2		TT-17903-1	BULKHEAD						44
006					1			TT-17902-11	HARDBACK						11
005						1		TT-17902-1	HARDBACK						11
004															
003															
002					1	1		-3	SEAL	FUEL RESISTANT RUBBER	1/8 DIA	138		MIL-P-5315	43
001								TT-17901	ASSY OF						

PARTS LIST

-11	1	50 4188		TANK #2	
-1	1	50 4188		TANK #1	
ITEM REQD	QTY PER END ITEM	MODEL	NEXT USING DRAWING	END ITEM NO EFFECTIVE ON	THRU

APPLICATION (USAGE) DATA

HEAT TREAT: NONE

FINISH: NONE

INSPECT PER MIL-I-6870 (LOGBOOK) CLASS II

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. DO NOT SCALE PRINT

DR BY VAN PUTTEN

COLUMBUS DIVISION
NORTH AMERICAN ROCKWELL CORPORATION
COLUMBUS, OHIO 43216

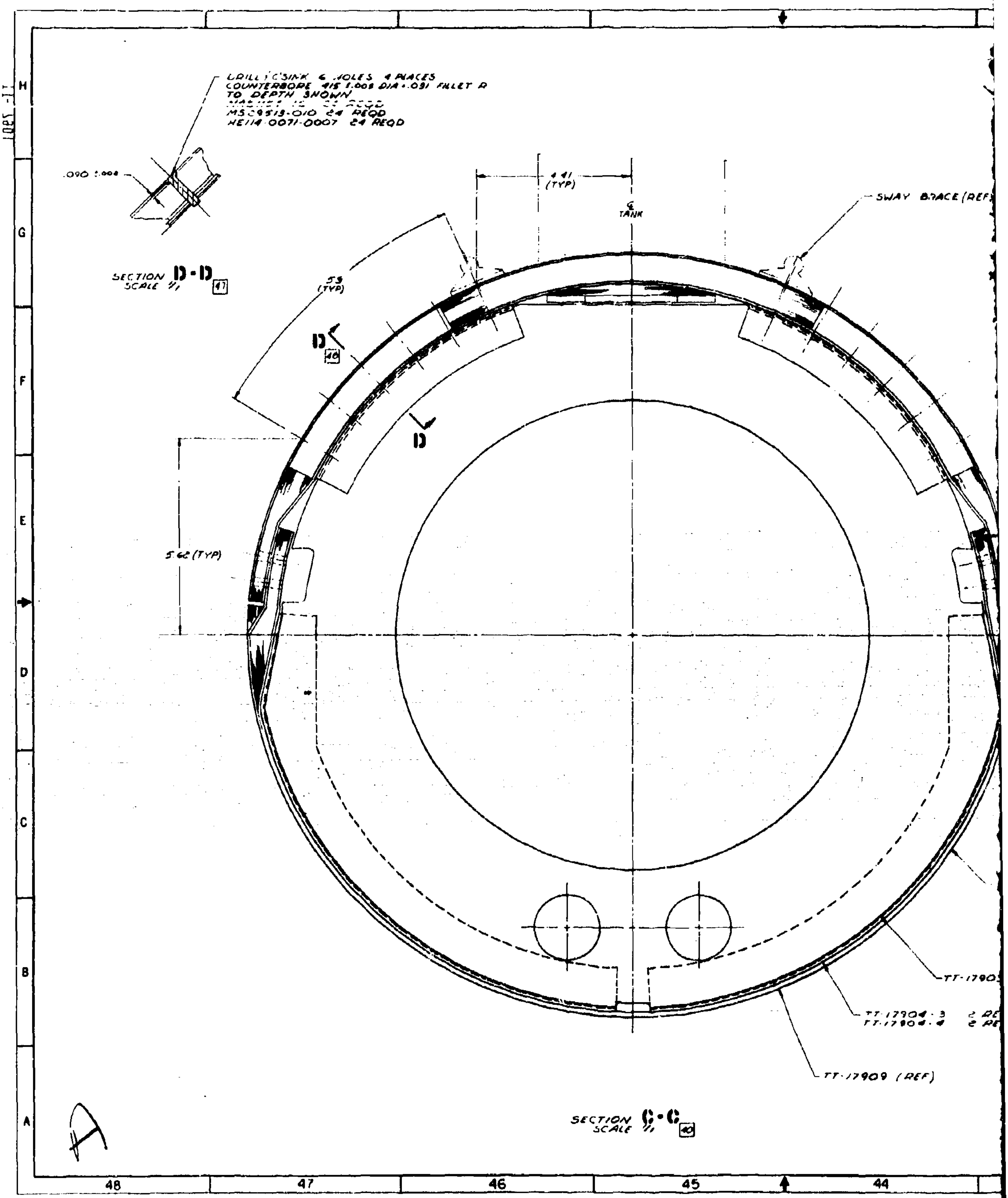
TANK - COMPLETE
150 GALLON COLLAPSIBLE WING
ASSY OF (TEST)

SIZE J | CODE IDENT NO 89372 | TT-17901

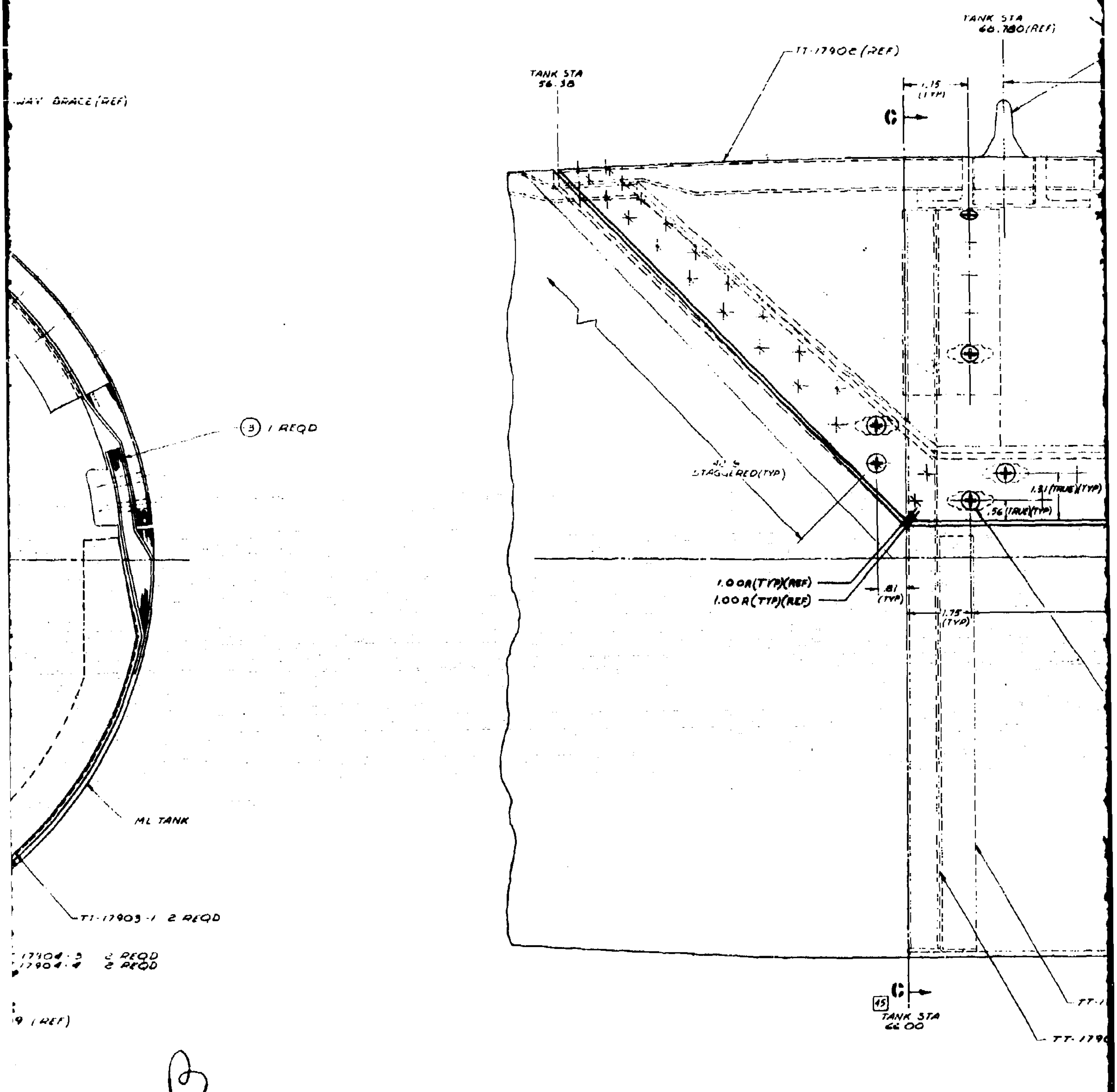
SCALE AS NOTED | SHEET 1 OF 2

5	4	3	2	1

Figure 49 Collapsible Tank Assembly

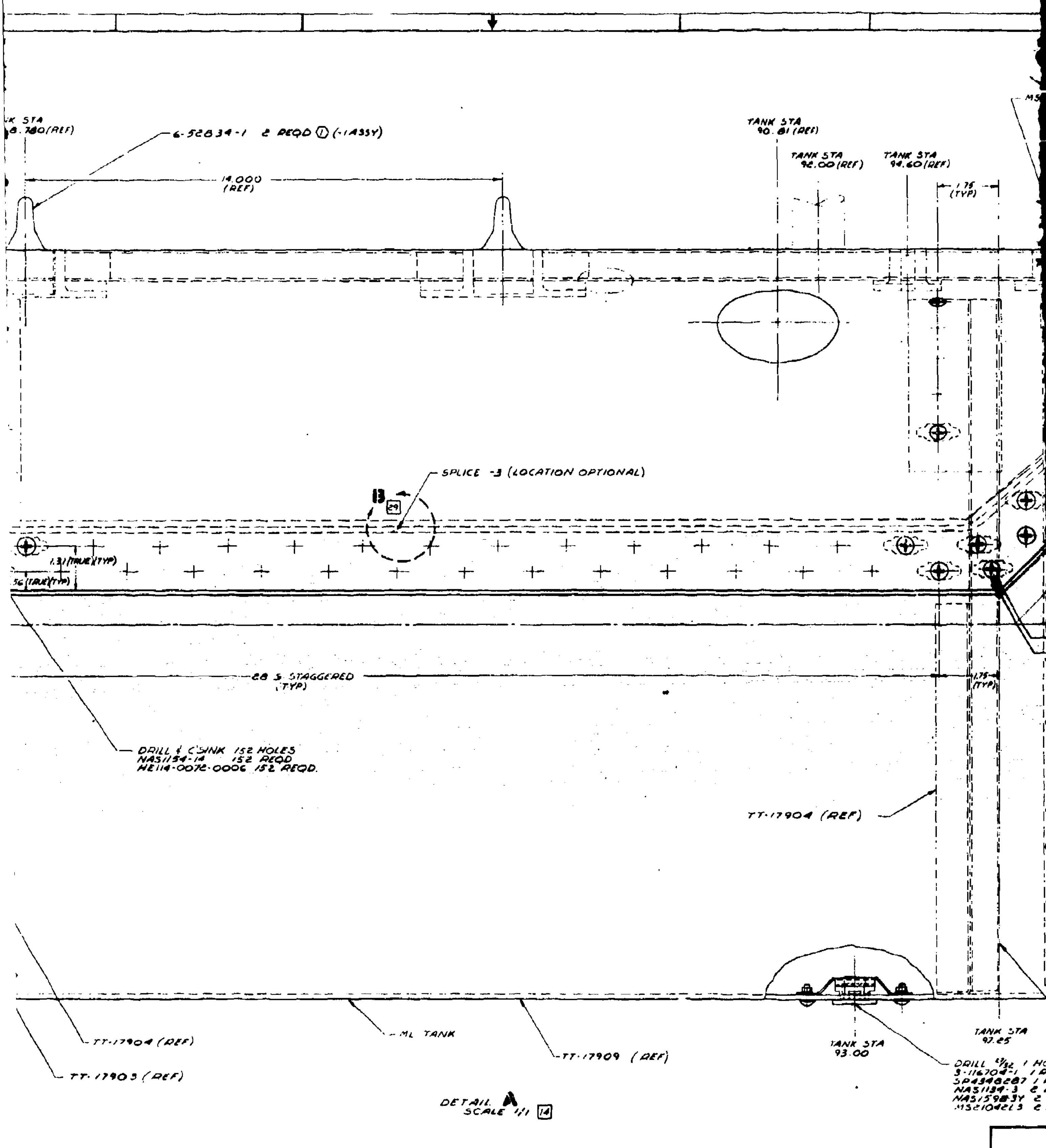


DRILL ; C'SINK 6 HOLES 4 PLACES
COUNTERBORE .415 ±.005 DIA ×.031 FILLET R
TO DEPTH SHOWN
MS29513-010 24 REQD
HE114-0071-0007 24 REQD
.090 ±.005
SECTION D-D
SCALE 1/1
4.41 (TYP)
℄ TANK
SWAY BRACE (REF)
.53 (TYP)
D
D
5.62 (TYP)
TT-1790
TT-17904-3 2 RE
TT-17904-4 2 RE
TT-17909 (REF)
SECTION C-C
SCALE 1/1
48
47
46
45
44
H
G
F
E
D
C
B
A

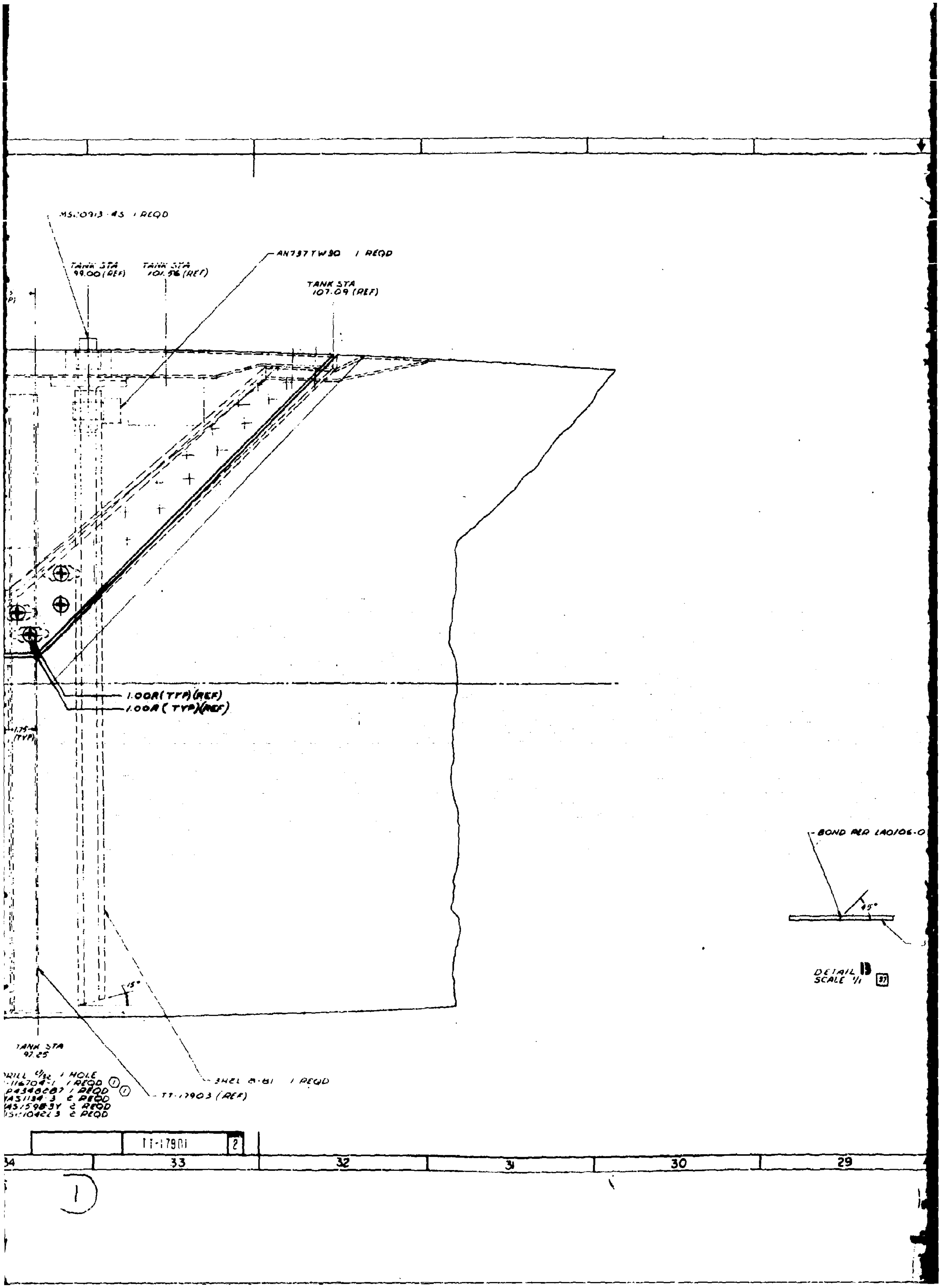


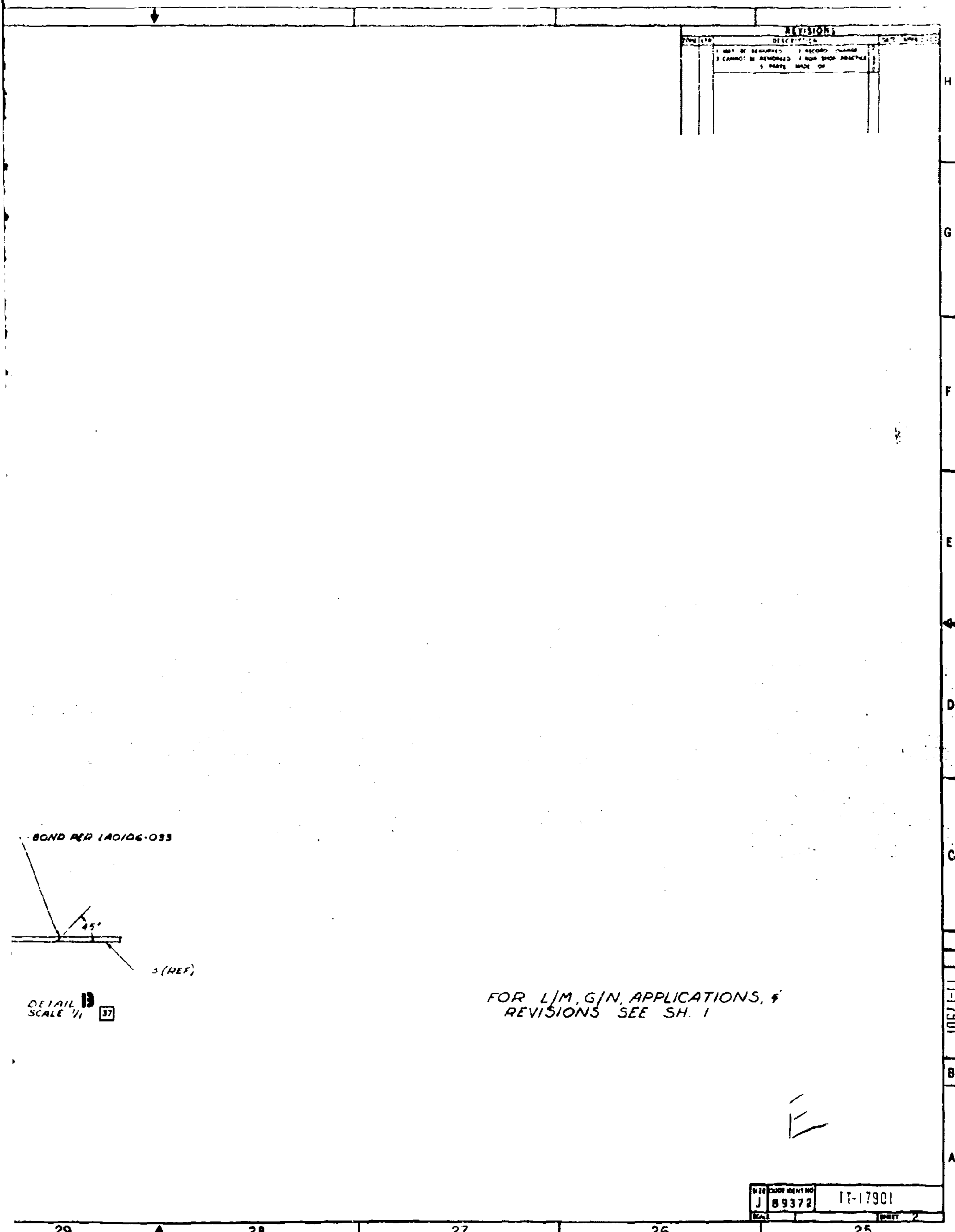
TT-17901 | 2

44	43	42	41	40	39

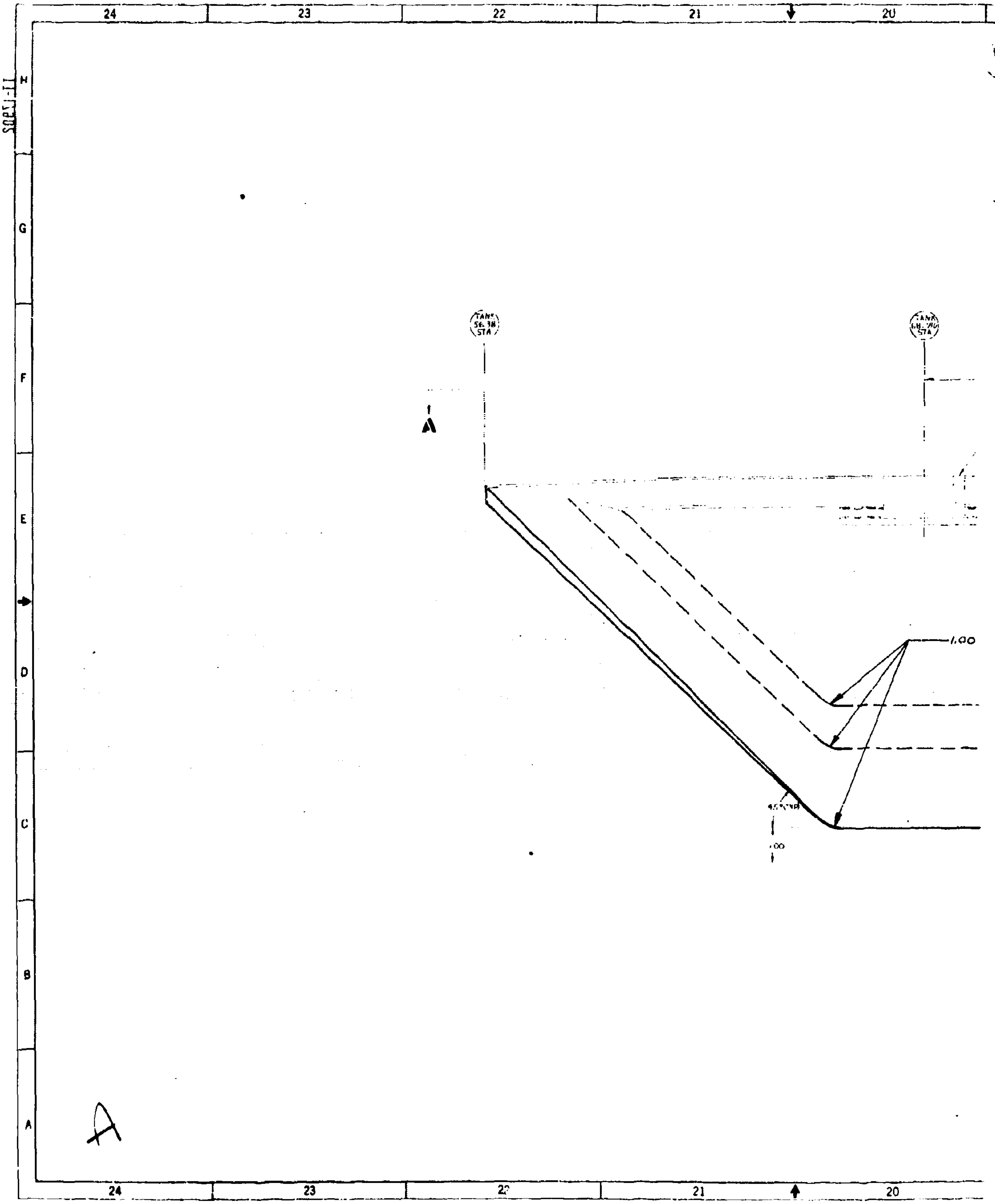


39 38 37 36 35 34


MS20913-4S 1 REQD
AN737TW30 1 REQD
TANK STA 99.00 (REF)
TANK STA 101.56 (REF)
TANK STA 107.09 (REF)
1.00R (TYP)(REF)
1.00R (TYP)(REF)
15°
TANK STA 97.25
1 HOLE
1 REQD
1 REQD
2 REQD
2 REQD
2 REQD
TT-17903 (REF)
1 REQD
BOND PER
45°
DETAIL B
SCALE 1/1
TT-17901
2
34
33
32
31
30
29
1

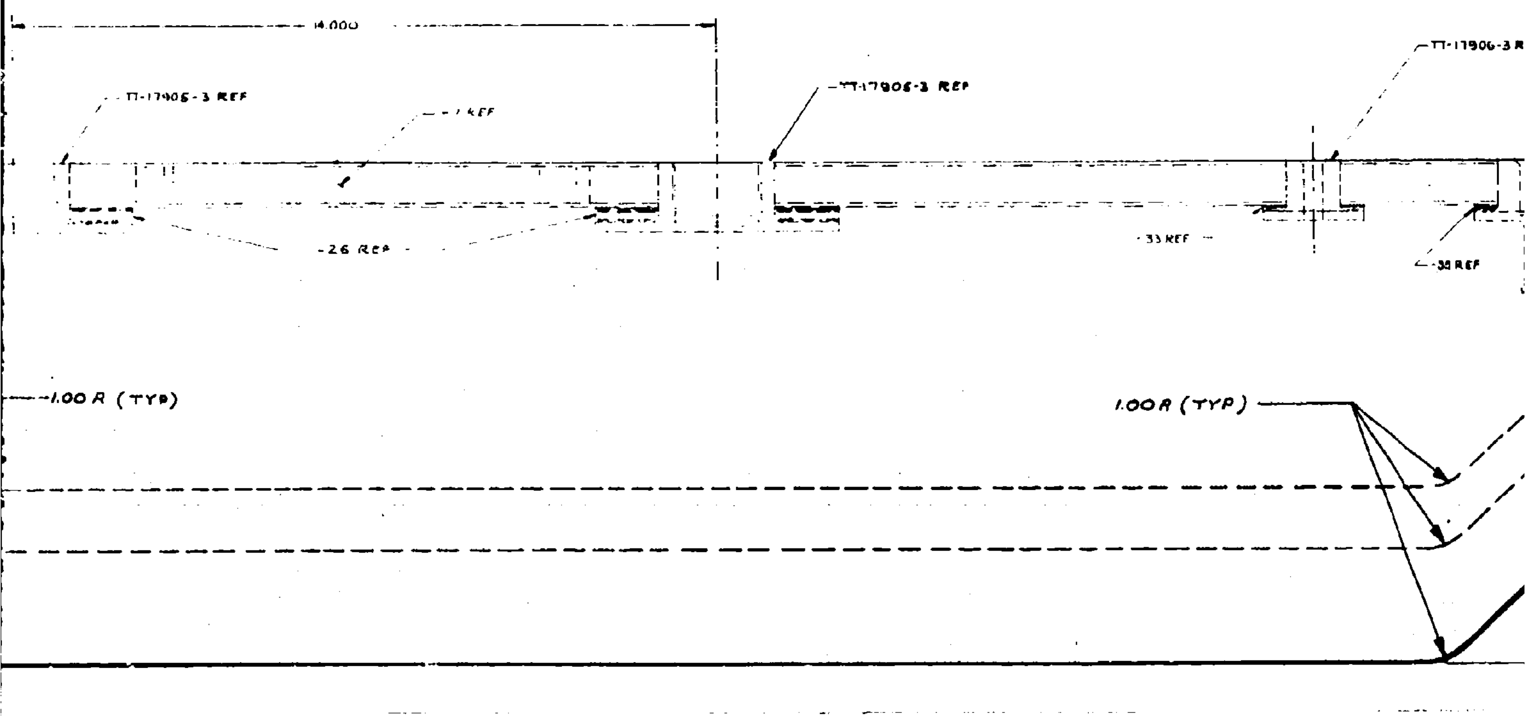


"Figure [illegible] Continued" Collapsible Tank Assembly



24
23
22
21
20
H
G
F
E
D
C
B
A
TANK 56.38 STA
A
1.00
45° TYP
1.00

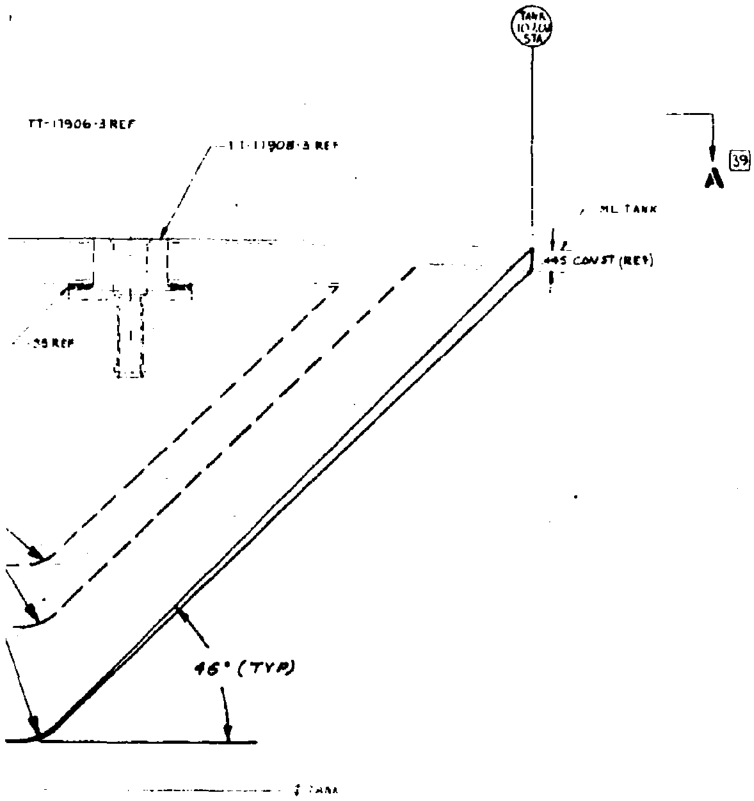
19	18	17	16	15



SIDE VIEW

TT-17902

19	18	17	16	15



TT-11906-3 REF
ML TANK
CONST (REF)
46° (TYP)

7. $\sqrt{}^{125}$ ALL MACHINED SURFACES
6. MACHINE PER NR SPEC LA0103-004

(2) 5. VENDOR ITEM SEE SPEC CONTROL DWG
(1) 4. GOVERNMENT FURNISHED AIRCRAFT EQUIPMENT (GFAE)
(A) 3. IDENTIFY PER NR SPEC ST0605NA0018

2. FOR CONTOURS & BEVELS SEE MD NOR 62-32
1. FABRICATE PER NR SPEC ST0605NA0018
NOTES: UNLESS OTHERWISE NOTED

D

TT-17902 | i

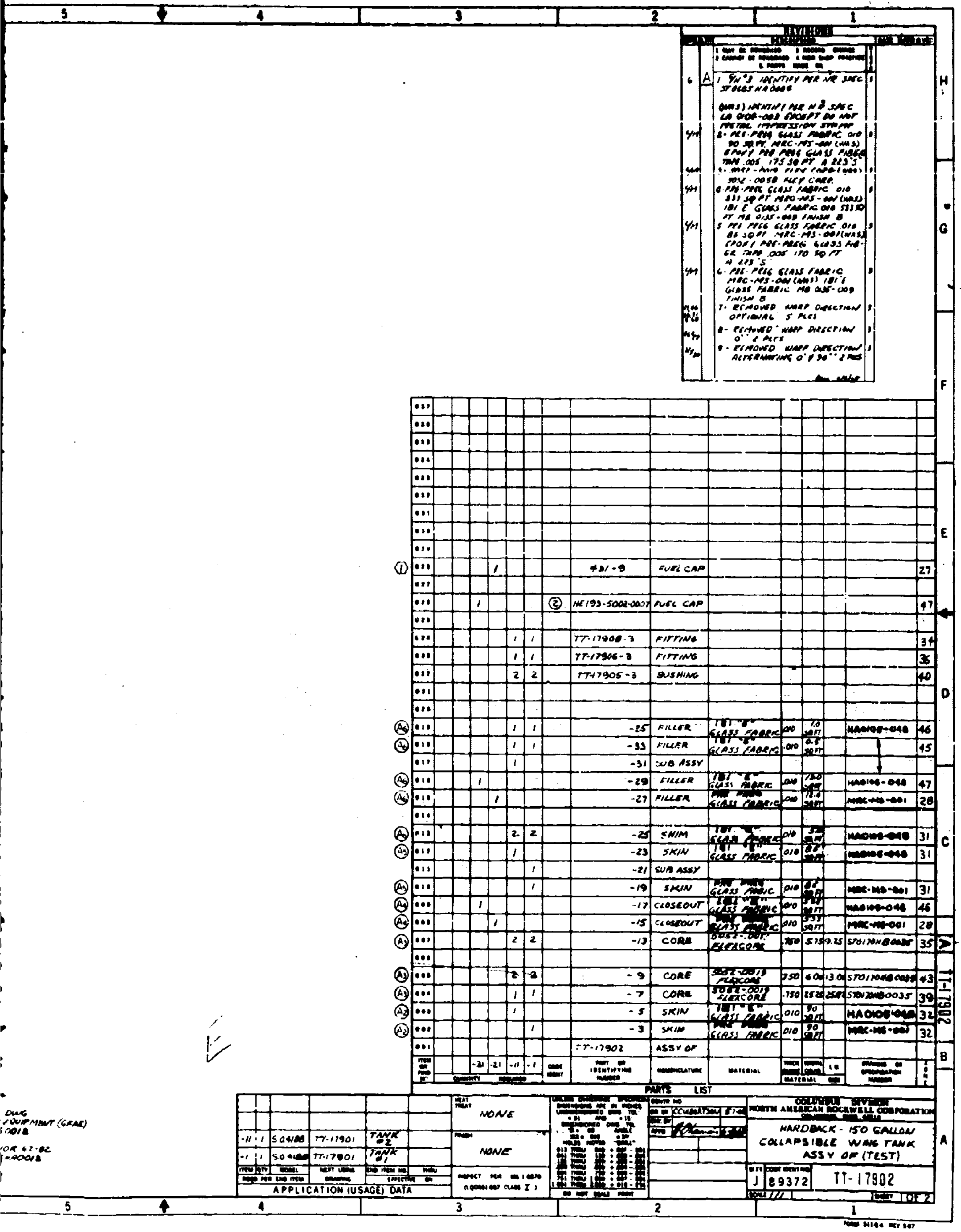
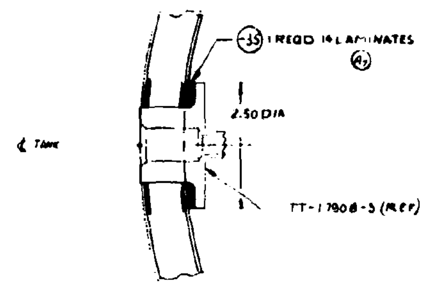
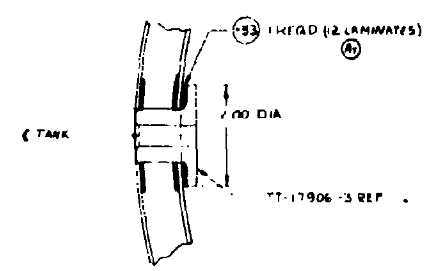


Figure 50 Hardback Design Drawing

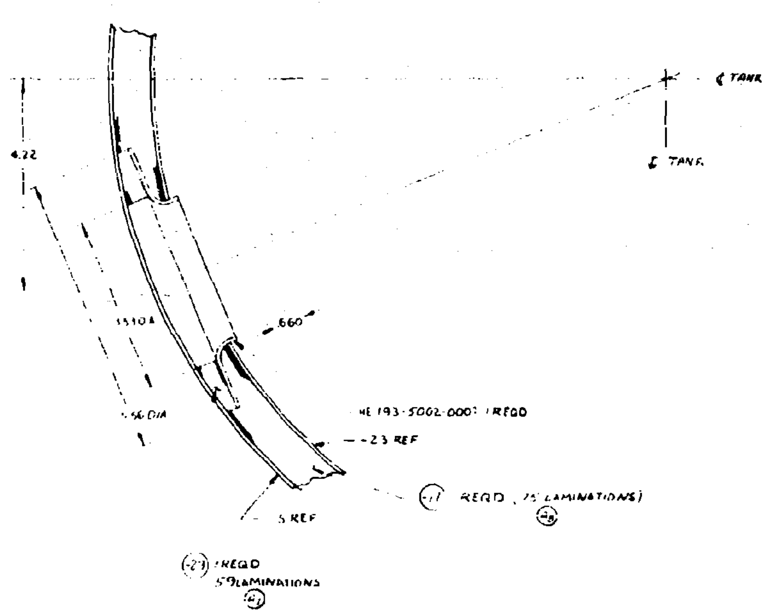


SECTION E-E 36



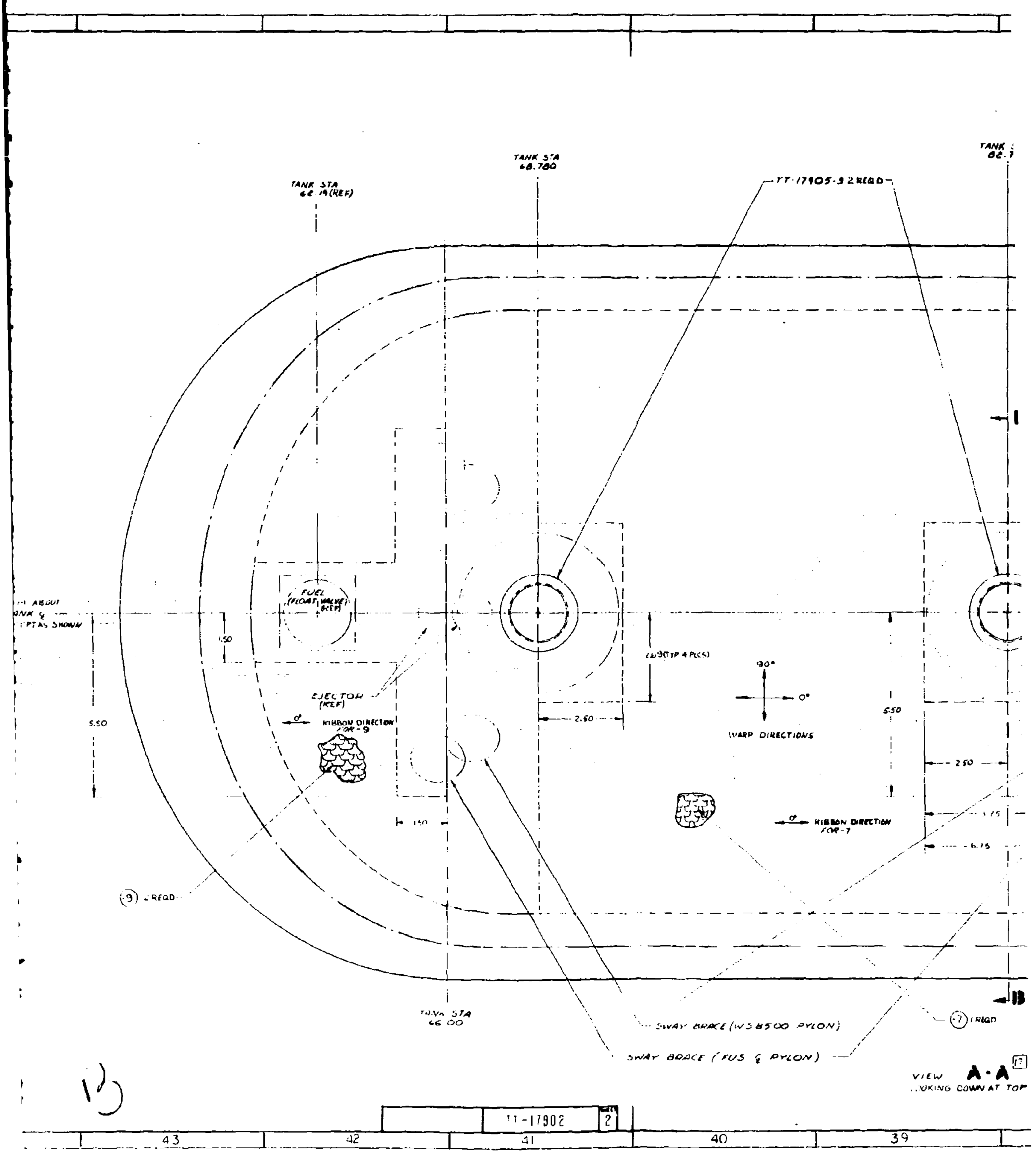
SECTION D-D 30

SYM ABOUT TANK ℄ EXCEPT AS SHOWN

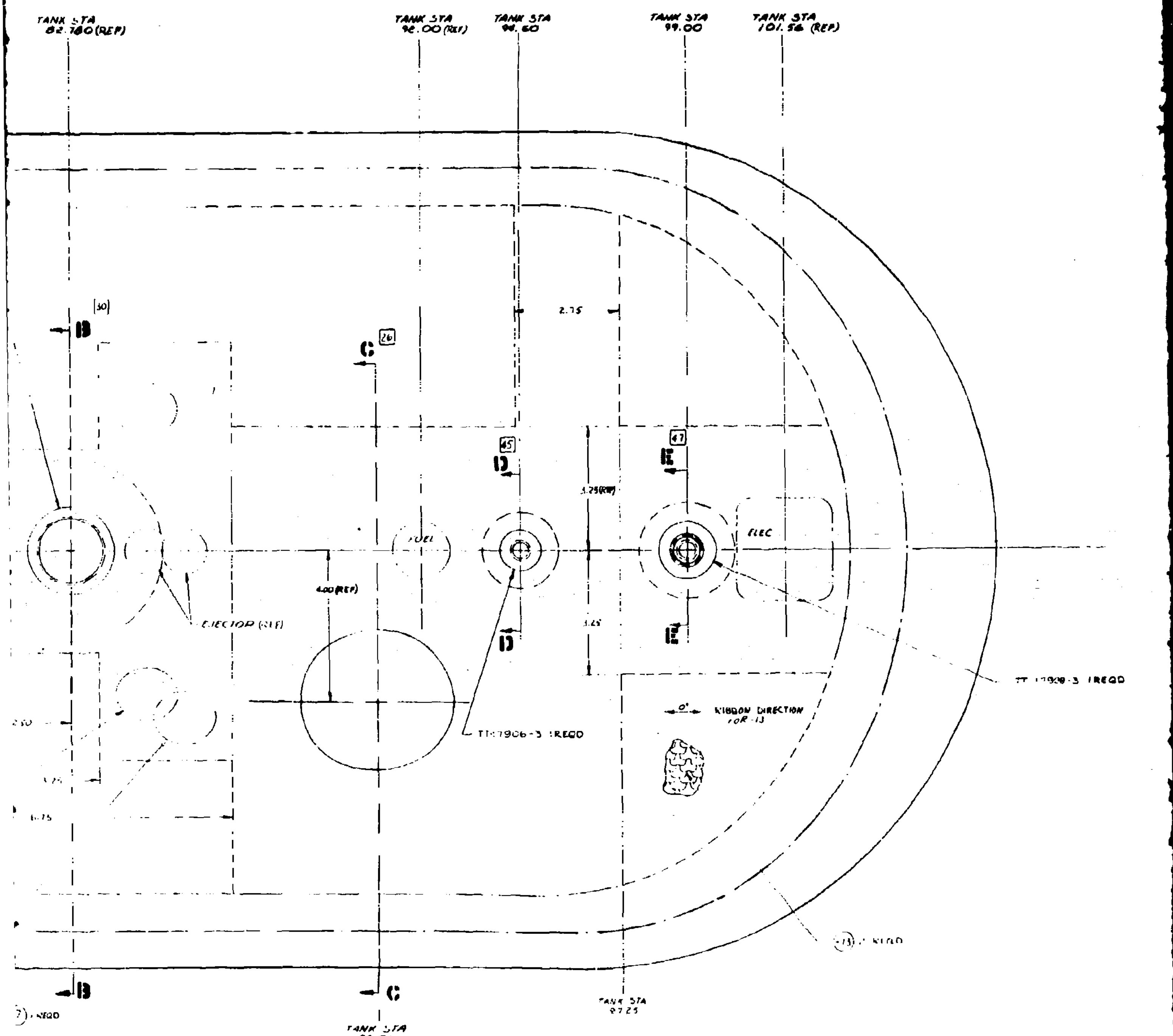


DETAIL F 28 (FOR -3 ASSY)

A



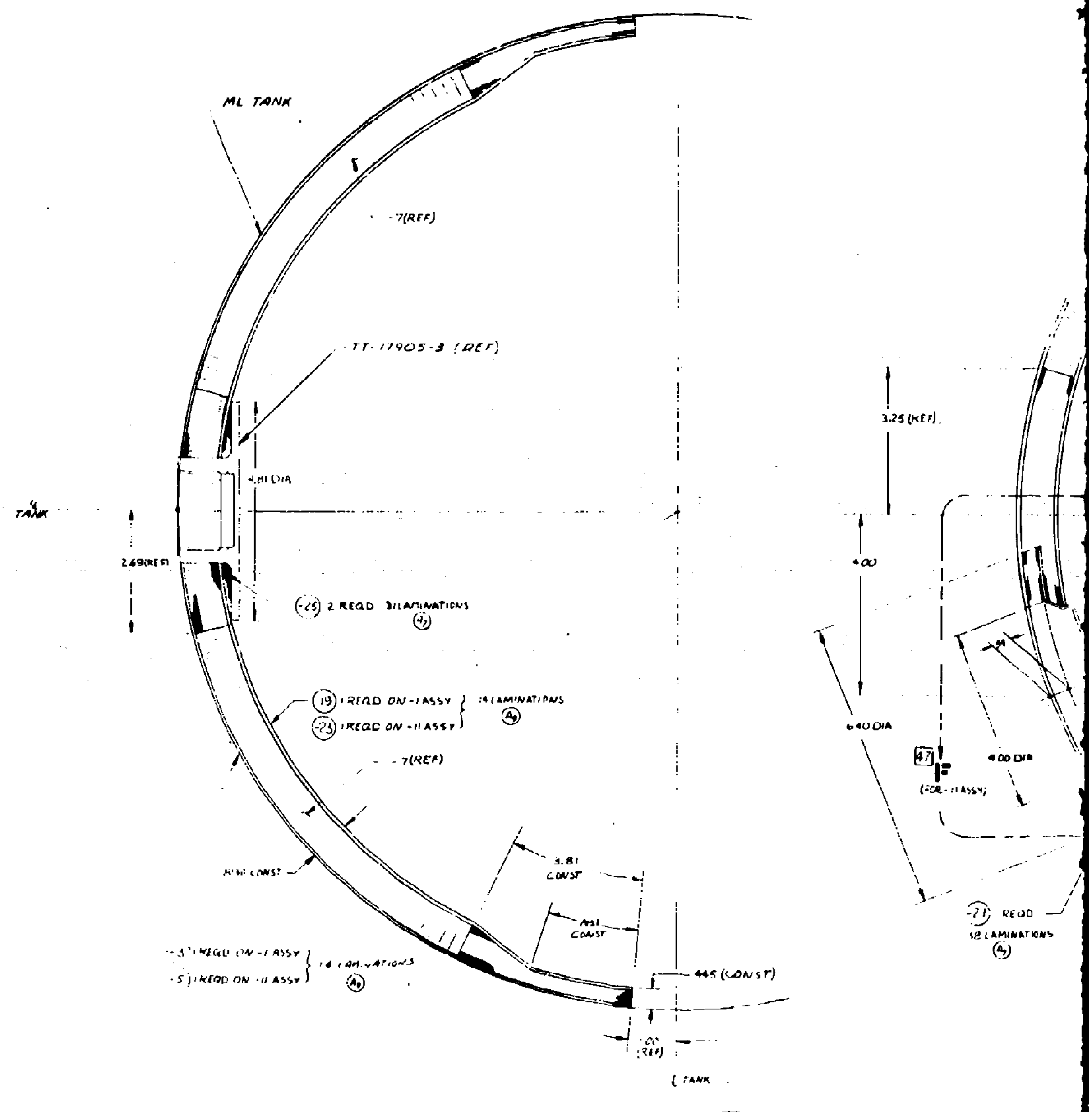
TANK STA 62.19 (REF)
TANK STA 68.780
TT-17905-3 2 REQD
FUEL (FLOAT VALVE) (REF)
1.50
5.50
EJECTOR (REF)
0°
RIBBON DIRECTION FOR-9
2.50
180°
0°
WARP DIRECTIONS
5.50
2.50
RIBBON DIRECTION FOR-7
9 2 REQD
7 1 REQD
TANK STA 66.00
SWAY BRACE (WS 85.00 PYLON)
SWAY BRACE (FUS & PYLON)
VIEW A-A
TT-17902
2
43
42
41
40
39



A-A

DOWN AT TOP OF HARDBACK

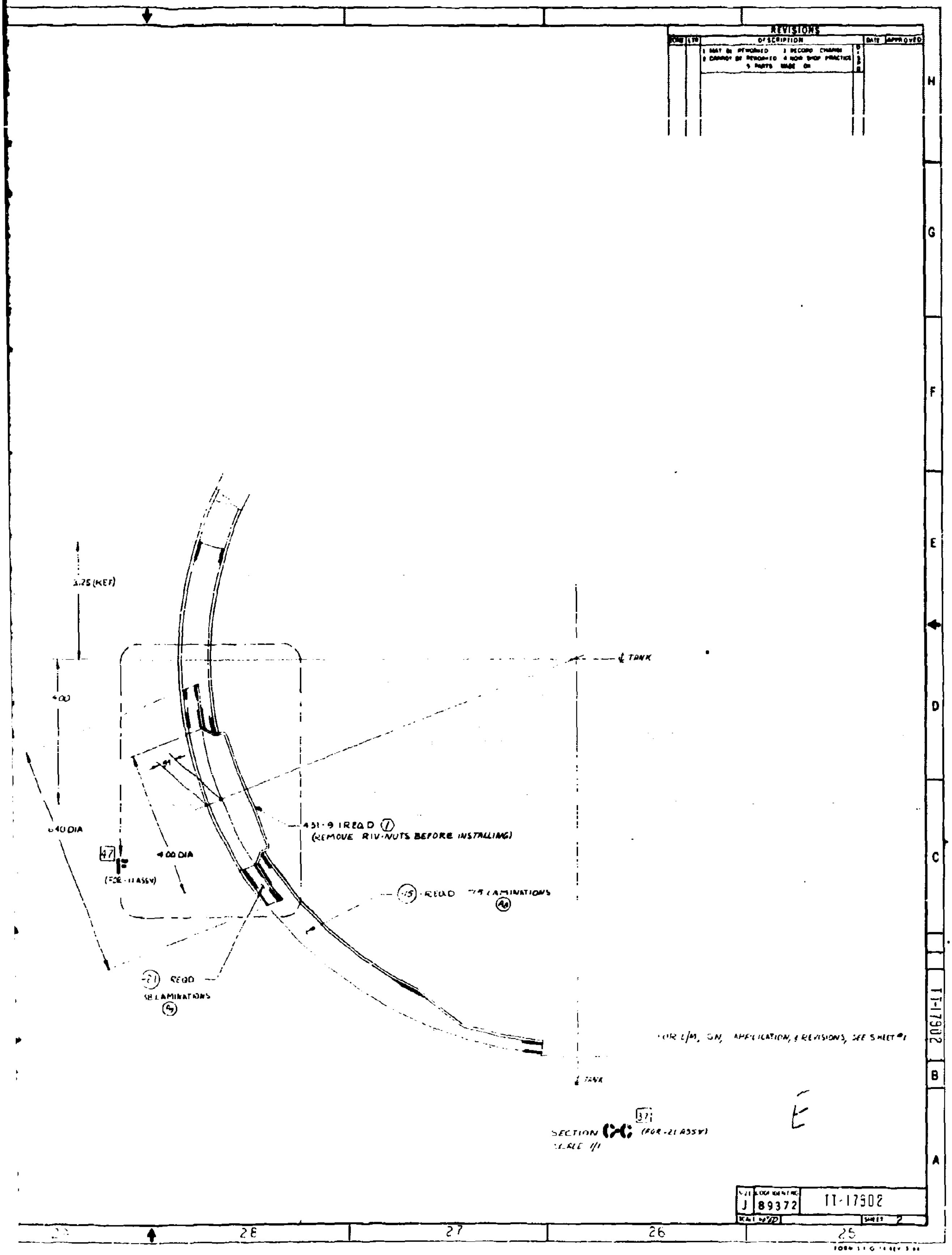
38 37 36 35 34



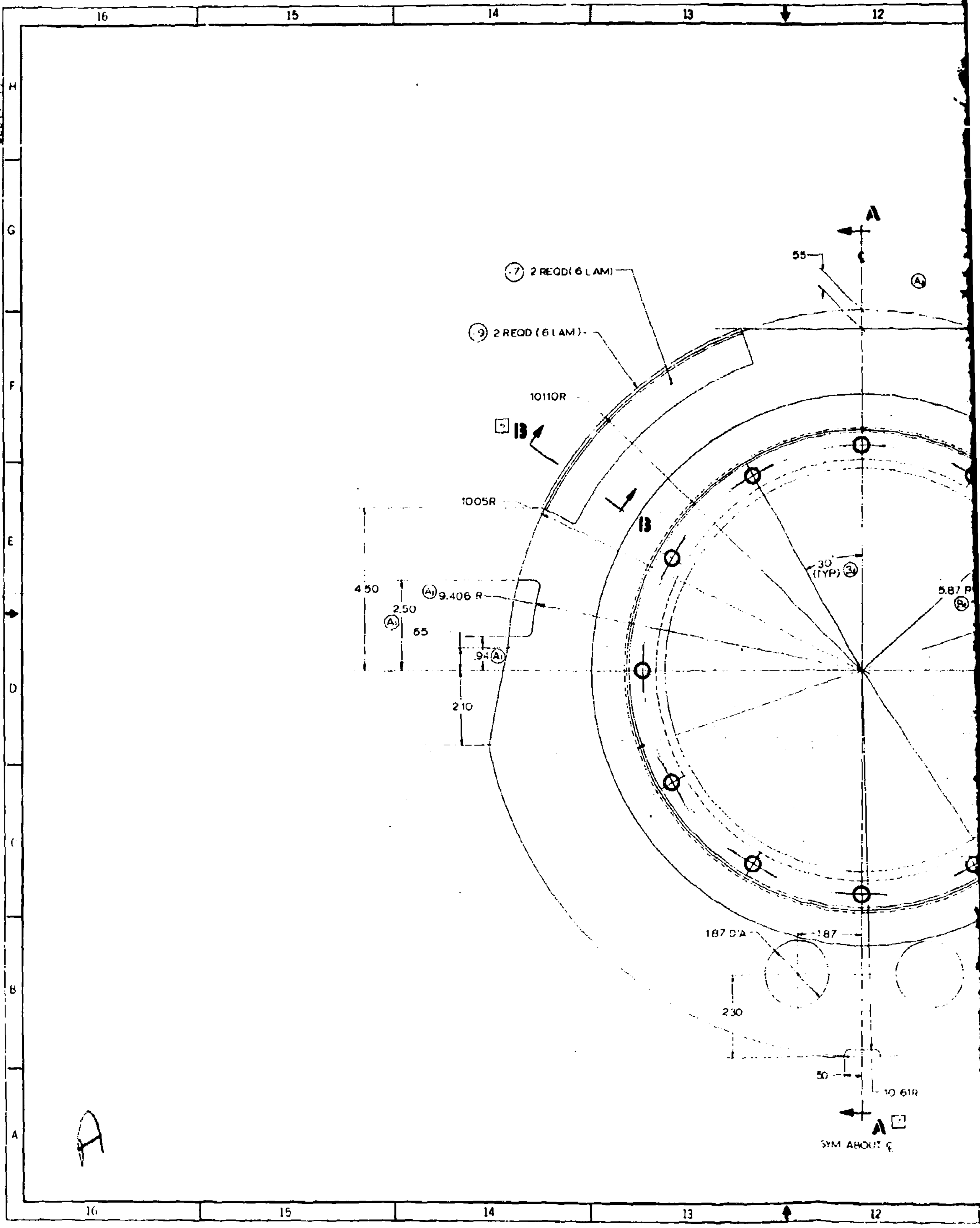
SECTION B-B 38

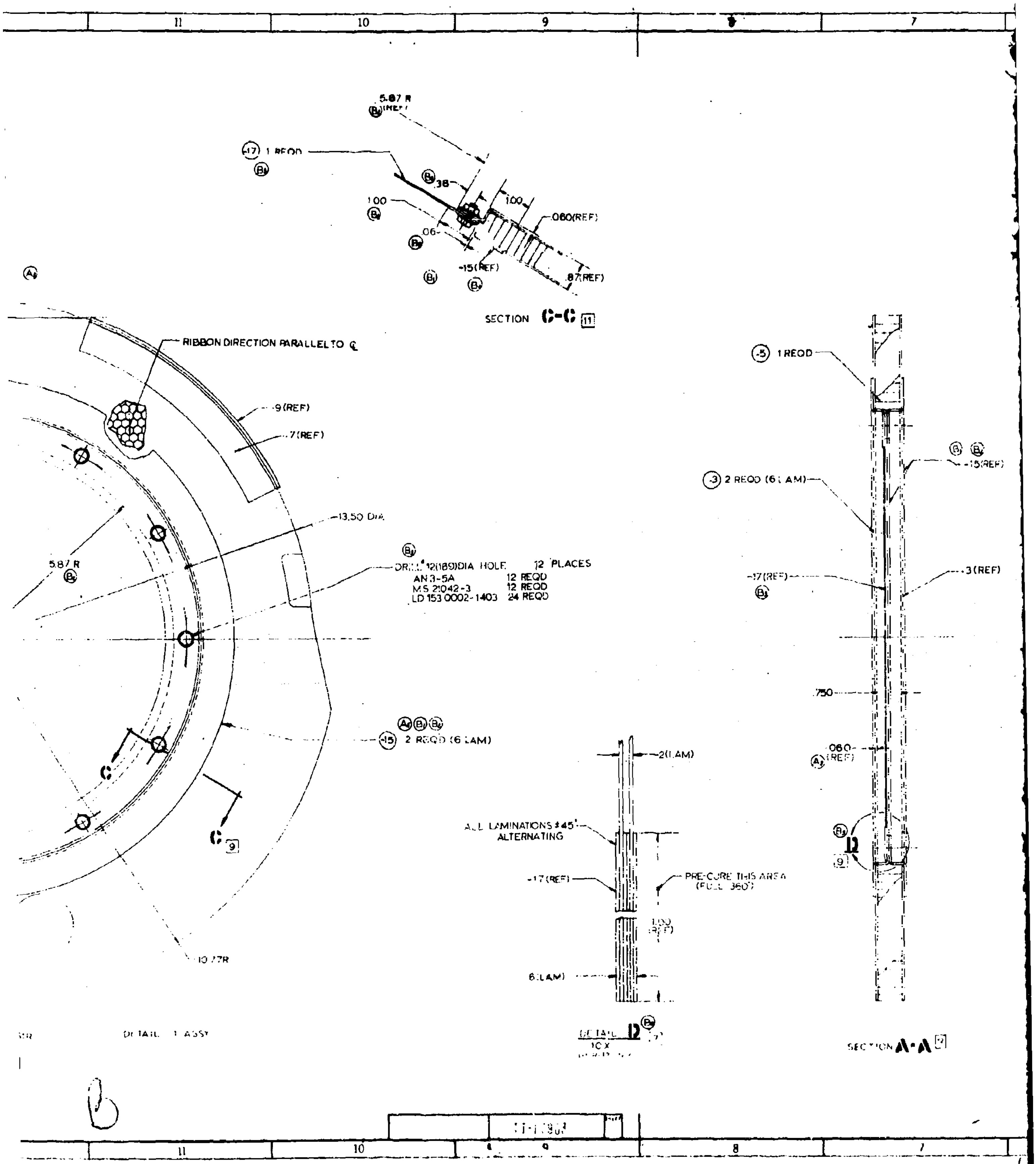
1

	33	32	31	30	29



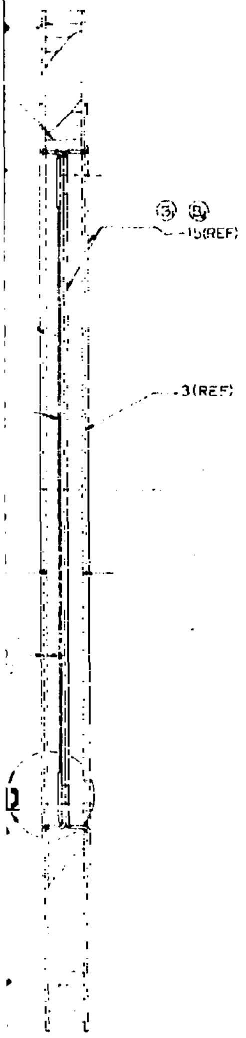
"Figure 50 Continued" Hardback Design Drawing

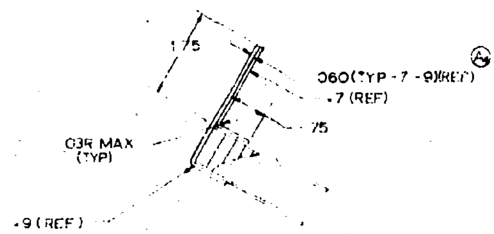

16
15
14
13
12
H
G
F
E
D
C
B
A
A
55
7 2 REQD (6 LAM)
9 2 REQD (6 LAM)
10110R
B
1005R
B
4.50
2.50
A1 9.406 R
A1
.65
.94 A1
2.10
.30 (TYP) 3
5.87 R
187 DIA
.187
2.30
.50
10.61R
A
SYM ABOUT ℄



11
10
9
8
7
5.87 R (REF)
-17 1 REQD
.38
1.00
.06
1.00
.060(REF)
-15(REF)
.87(REF)
SECTION C-C 11
RIBBON DIRECTION PARALLEL TO ℄
-9(REF)
-7(REF)
-13.50 DIA
5.87 R
DRILL .12(189)DIA HOLE 12 PLACES
AN 3-5A 12 REQD
MS 21042-3 12 REQD
LD 153 0002-1403 24 REQD
-15 2 REQD (6 LAM)
C
C 9
10.77R
-5 1 REQD
-3 2 REQD (6 LAM)
-15(REF)
-17(REF)
-3(REF)
.750
.060 (REF)
D 9
-2(LAM)
ALL LAMINATIONS ±45° ALTERNATING
-17(REF)
PRE-CURE THIS AREA (FULL 360°)
1.00 (REF)
6(LAM)
DETAIL - ASSY
DETAIL D
10 X
SECTION A-A

7	6	5	4	3	2





SECTION B-B
DETAIL -7

SECTION A-A

ITEM OR FIND NO	QUANTITY REQUIRED -1	CODE IDENT	PART OR IDENTIFYING NUMBER	NOMEN
037				
036				
035				
034				
033				
032				
031				
030				
029				
028				
027				
026				
025				
024				
023				
022				
021				
020				
019				
018				
017				
016				
015				
(B) 014	12		AN3-5A	B
(B) 013	12		MS 21042-3	N
(B) 012	24		LD153-0002-1403	WAS
011				
010				
009				
(B) 008			-17	S... BA
(B) 007	2		-15	ZE
(B)(A) 006	3		-13	CHA
(A) 005	2		-9	CL
(A) 004	2		-7	CL
003	1		-5	CO
002	2		-3	SK
001			TT-17903	BULK ASSY

PARTS

-1	2	S04188	TT-17901		
ITEM NO	QTY PER ASSY	MODEL	NEXT USING DRAWING	END ITEM NO EFFECTIVE ON	THRU

APPLICATION (USAGE) DATA

HEAT TREAT: NONE

FINISH: NONE

INSPECT PER MIL-I-6870

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DO NOT SCALE PRINT

(B)(A) 6 ... FASTENERS PER NR SPEC LA 0101-001

(B)(A) 5 ... PER NR SPEC STD 605HA 0012

4 MACHINE PER NR SPEC LA0103-004

3 FILLET R .15

(A) 2 FABRIC ORIENTATION OPTIONAL

(A) 1 FABRICATE PER NR SPEC STD 605HA 0012

NOTES UNLESS OTHERWISE NOTED

7	6	5	4	3	2

REVISIONS			
ZONE	LTR	DESCRIPTION	
14	A	1- 2 .0(WAS) 2.60, .94(WAS) 1.10 & 9.405(WAS) 9.50	
12		2- REM 1.45 DIM	
4		3- .060(REF)(WAS) .060	
4		4- .060(-7, -9)(REF)(WAS) .060 (TYP -7, -9)	
		5- ADD -13 CHANNEL, ALL REQD LOCATING DIMS, VIEWS & CALL-OUTS TO	
		6- [illegible]	
		7- [illegible] 605 HA 0004 [illegible] STD 106 HA 0006	
		8- [illegible]	
6		9- [illegible]	
6		10- [illegible] SPEC STD 605 HA 0006	
	B	1- DELETED -13 3 REQD FROM [illegible]	
		2- ADD -15 2 REQD TO [illegible] ALL LOCATING DIMS, VIEWS & PROFILES	
		3- ADD -17 1 REQD TO [illegible] ALL LOCATING DIMS, VIEWS & PROFILES	3

060(TYP -7 -9)(REF)

-7 (REF)

75

13-13

-7

ITEM OR FIND NO	QUANTITY REQUIRED -1	CODE IDENT	PART OR IDENTIFYING NUMBER	NOMENCLATURE	MATERIAL	THICK OR DIA	WIDTH OR DIA	L/O SIZE	DRAWING OR SPECIFICATION NUMBER	ZONE
037										
036										
035										
034										
033										
032										
031										
030										
029										
028										
027										
026										
025										
024										
023										
022										
021										
020										
019										
018										
017										
016										
015										
(B) 014	12		AN3-5A	BOLT						
(B) 013	12		MS 21042-3	NUT						
(B) 012	24		LD153-0002-1404	WASHER						
011										
010										
009										
(B) 008	1		-17	SLOSH BAFFLE	181 E GLASS FABRIC			25 sq ft	MIL-C-9084 TYPE VIII	
(B) 007	2		-15	ZEE	181 E GLASS FABRIC			40 sq ft	MIL-C-9084 TYPE VIII	
(B)(A) 006	3		-13	CHANNEL	181 E GLASS FABRIC			.90 sq ft	MIL-C-[illegible] TYPE [illegible]	
(A) 005	2		-9	CLIP	181 E GLASS FABRIC	—	—	1.30 sq ft	MIL-C-9084 TYPE VIII	14
(A) 004	2		-7	CLIP	181 E GLASS FABRIC	—	—	.90 sq ft	MIL-C-9084 TYPE VIII	14
003	1		-5	CORE	ALFONE COMB 3/16-5052.003	.750	220	220	BO107-019	8
002	2		-3	SKIN	181 E GLASS FABRIC	—	—	480 sq ft	MIL-C-9084 TYPE VIII	8
001			TT-17903	BULKHEAD ASSY OF						

PARTS LIST

-1	2	SO-189	TT-17901		
ITEM	QTY	MODEL	NEXT USING DRAWING	END ITEM NO EFFECTIVE ON	THRU

APPLICATION (USAGE) DATA

HEAT TREAT: NONE

FINISH: NONE

INSPECT PER MIL-I-6870, N 30801-001 CLASS 3

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. DO NOT SCALE PRINT

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION, COLUMBUS, OHIO

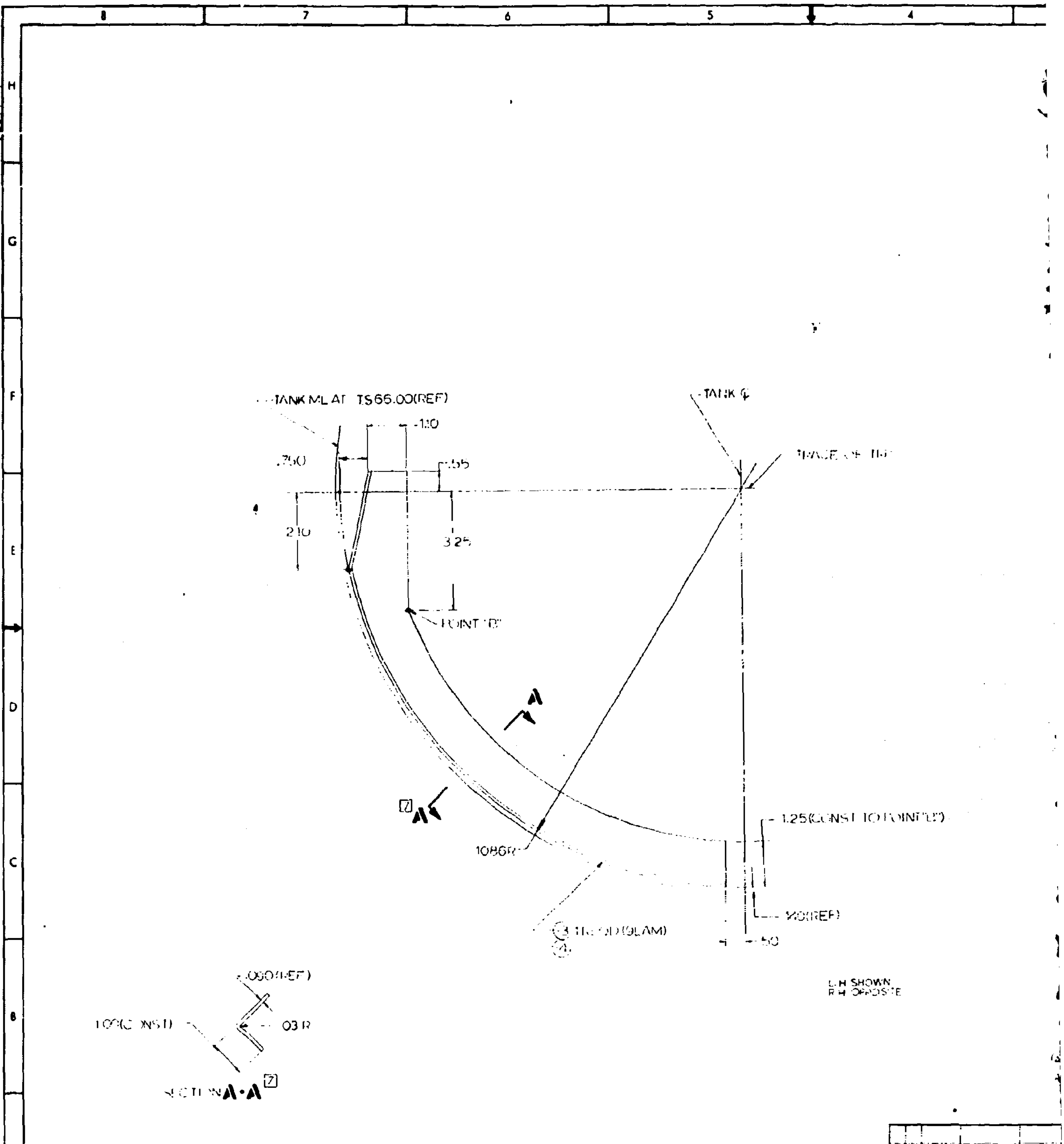
BULKHEAD - COLLAPSIBLE WING TANK, ASSY OF (TEST)

SIZE J | CODE IDENT 89372 | TT-17903

TT-17903

Figure 51 Bulkhead and Slosh Baffle

109



(A) 5 IDENTIFY PER NR SPEC ST 06... HA0012

4 ALL MACHINED SURFACES TO BE ✓
3 MACHINE PER NR SPEC LA0103-004
2 FABRIC ORIENTATION OPTIONAL
(A) 1 FABRICATE PER NR SPEC ST 0605 HA 0012
NOTES UNLESS OTHERWISE NOTED

4	2	S04188	TT1701	
3	2	S04188	TT1750	

APPLICATION (USAGE) DATA

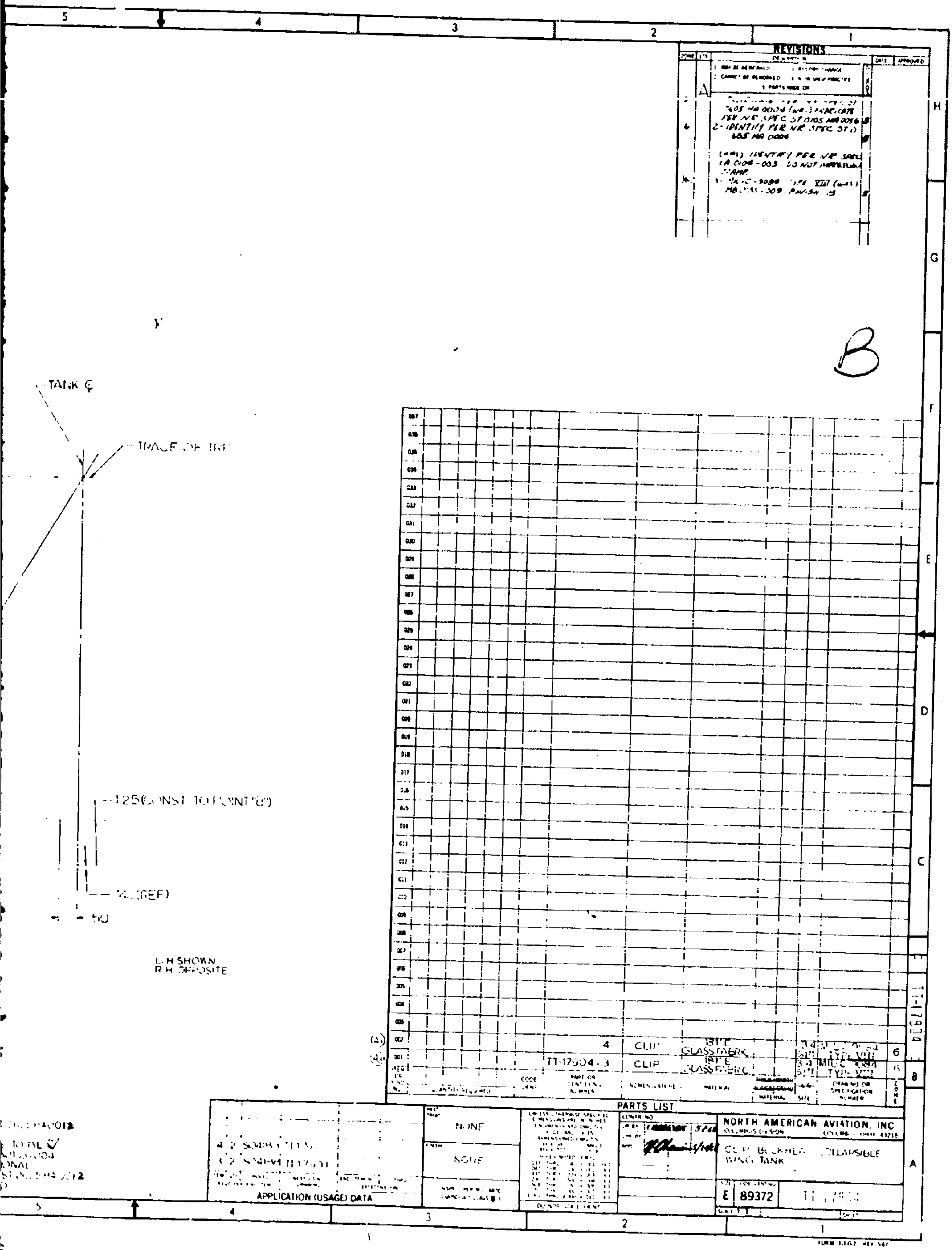
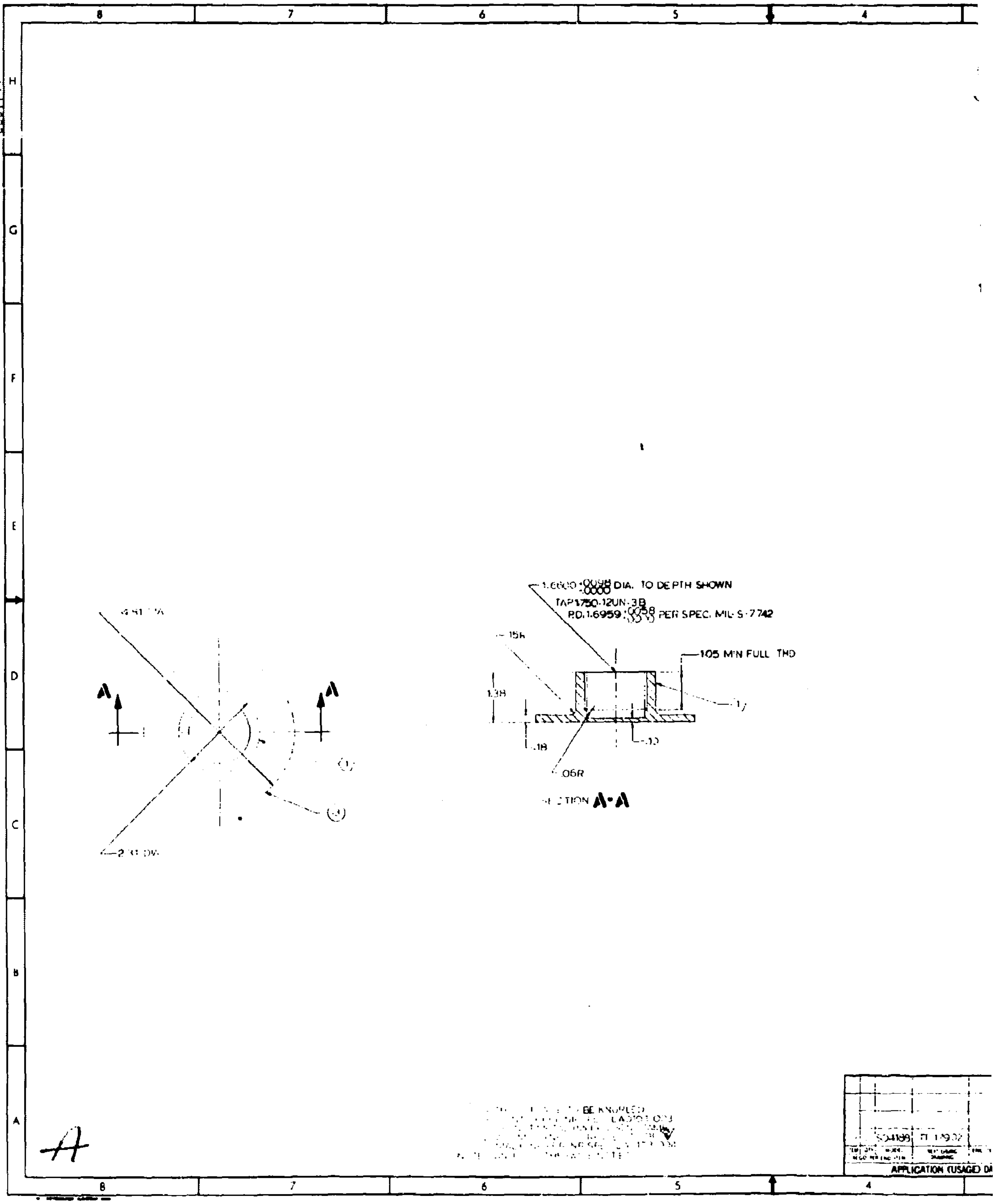


Figure 52 Bulkhead Attach Clip


1.6600 DIA. TO DEPTH SHOWN
TAP 1.750-12UN-3B
P.D. 1.6959 PER SPEC. MIL-S-7742
.105 MIN FULL THD
.38
.18
.06R
SECTION A-A
A
A
APPLICATION (USAGE) DATA

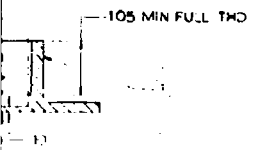
REVISIONS

1. MAY BE REWORKED 3. RECORD CHANGE
2. CANNOT BE REWORKED 4. NEW SHOP PRACTICE
5. PARTS MADE ON

B

... TO DEPTH SHOWN

... PER SPEC. MIL-S-7742



TT-17905-1 BUSHING

ITEM OR FIND NO. | QUANTITY REQUIRED | CODE IDENT | PART OR IDENTIFYING NUMBER | NOMENCLATURE | MATERIAL | MATERIAL | ZONE

PARTS LIST

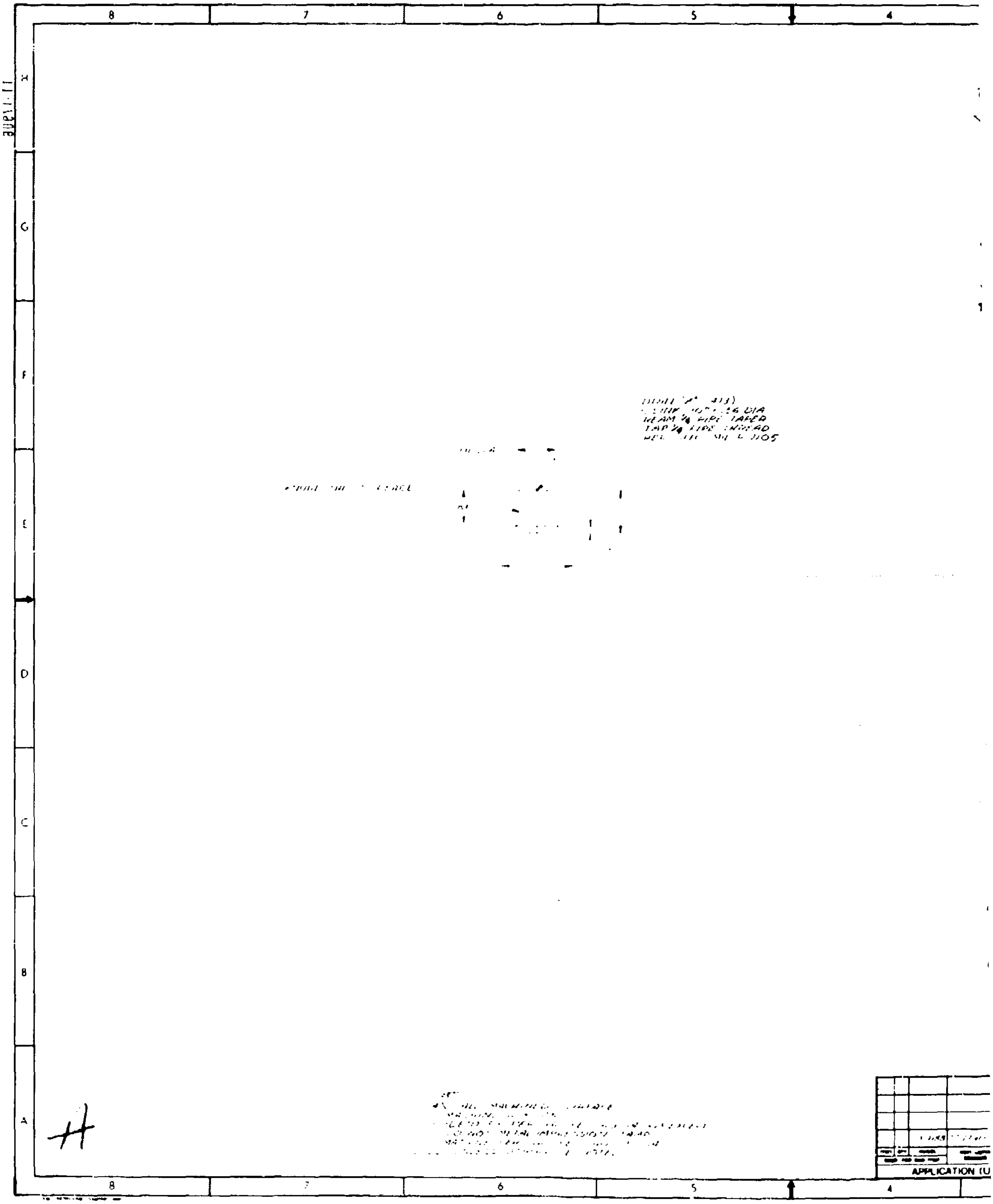
APPLICATION (USAGE) DATA

DO NOT SCALE PRINT

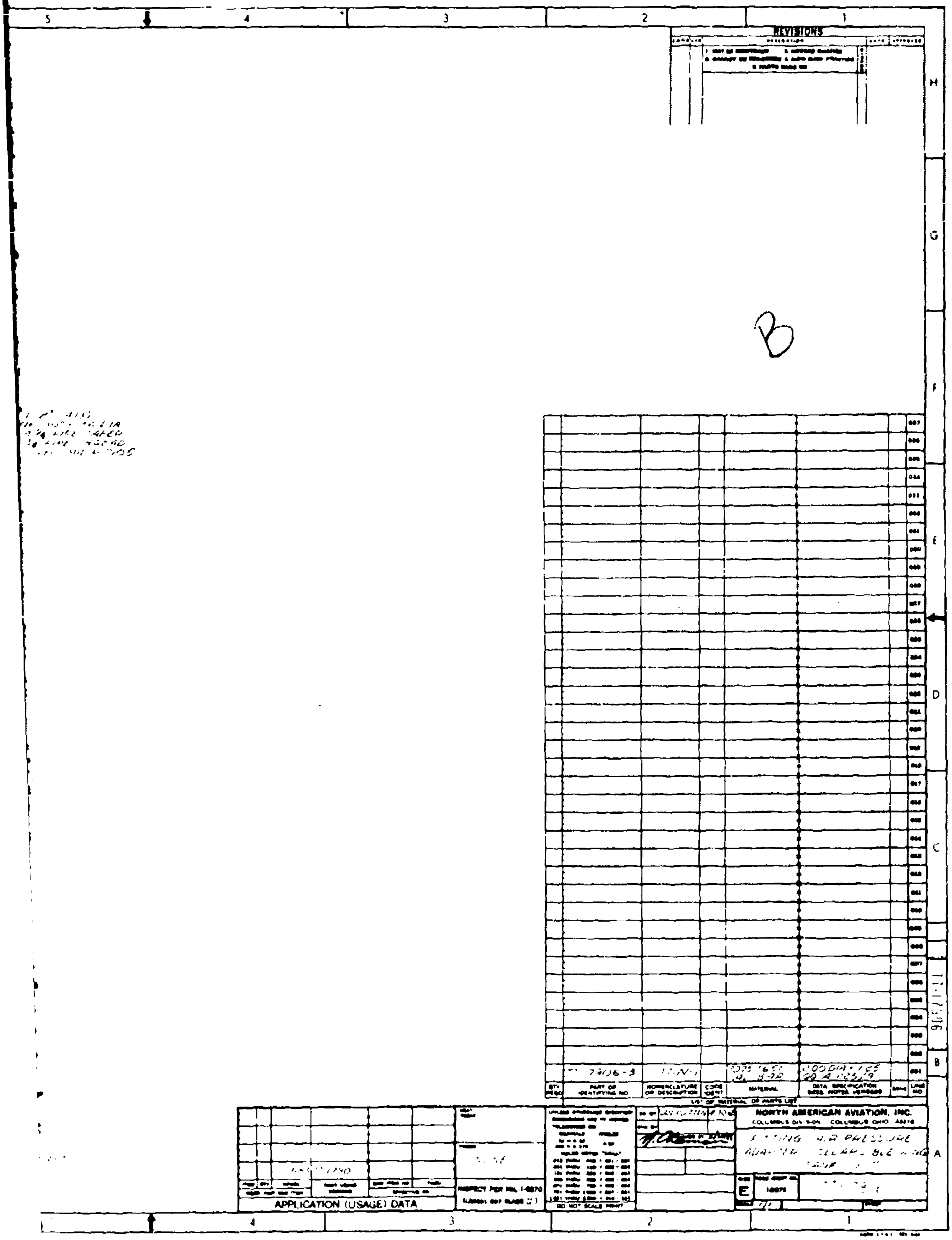
NORTH AMERICAN AVIATION, INC
COLUMBUS DIVISION

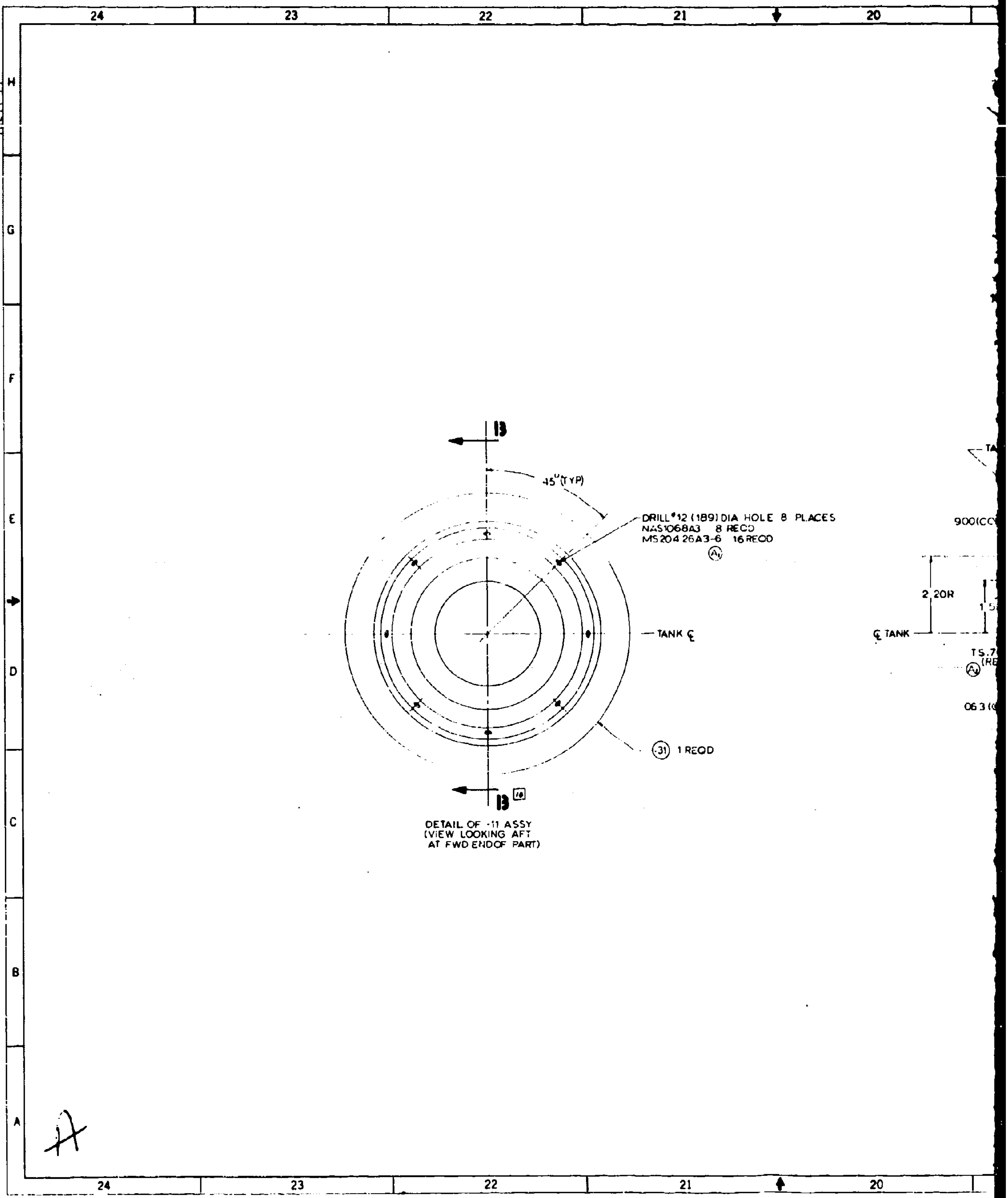
BUSHING - COLLAPSIBLE WING TANK SUSPENSION LUG (TEST)

E 89372 TT 17905

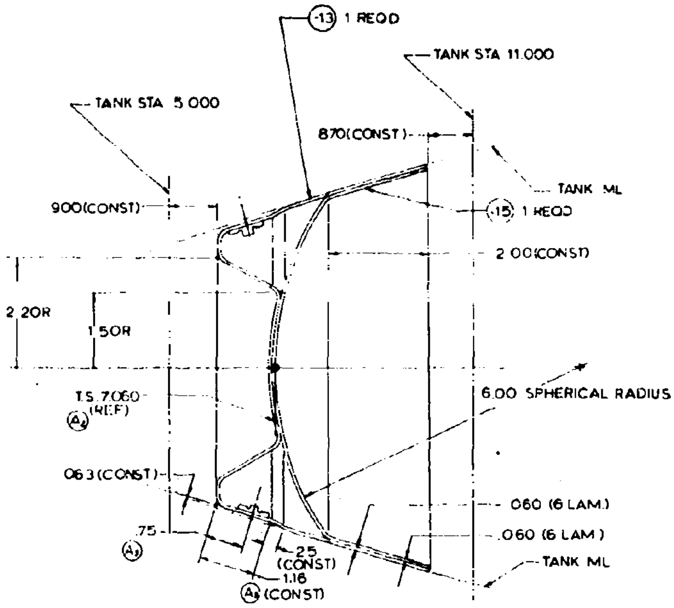


8
7
6
5
4
H
G
F
E
D
C
B
A
REAM ¼ PIPE TAPER
TAP ¼ PIPE THREAD
APPLICATION (U


REVISIONS
B
APPLICATION (USAGE) DATA
INSPECT PER MIL-I-6870
DO NOT SCALE PRINT
LIST OF MATERIAL OR PARTS LIST
QTY REQD
PART OR IDENTIFYING NO
NOMENCLATURE OR DESCRIPTION
CODE IDENT
MATERIAL
DATA SPECIFICATION SIZE, NOTES, VENDORS
ZONE
LINE NO
NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION COLUMBUS OHIO
E

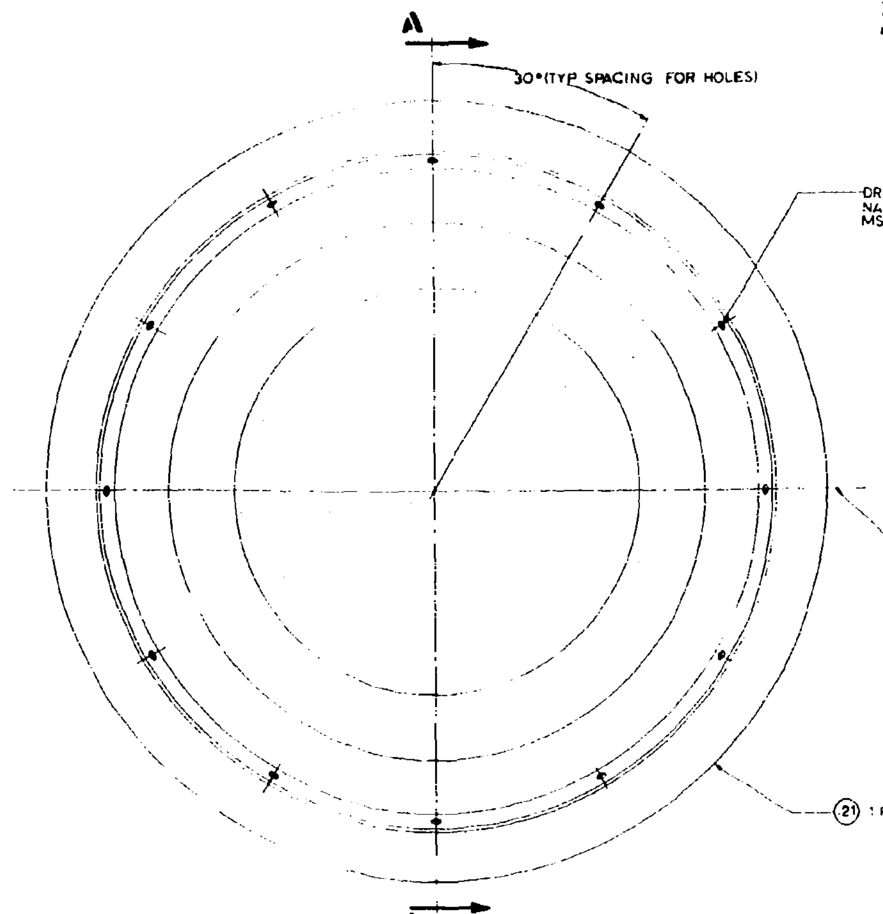


24
23
22
21
20
H
G
F
E
D
C
B
A
B
45° (TYP)
DRILL #12 (.189) DIA HOLE 8 PLACES
NAS1068A3 8 REQD
MS20426A3-6 16 REQD
TANK ℄
31 1 REQD
B
DETAIL OF -11 ASSY
(VIEW LOOKING AFT
AT FWD END OF PART)
900(CO
2.20R
℄ TANK



SECTION 13-13 [22]
(VIEW LOOKING OUTBD)

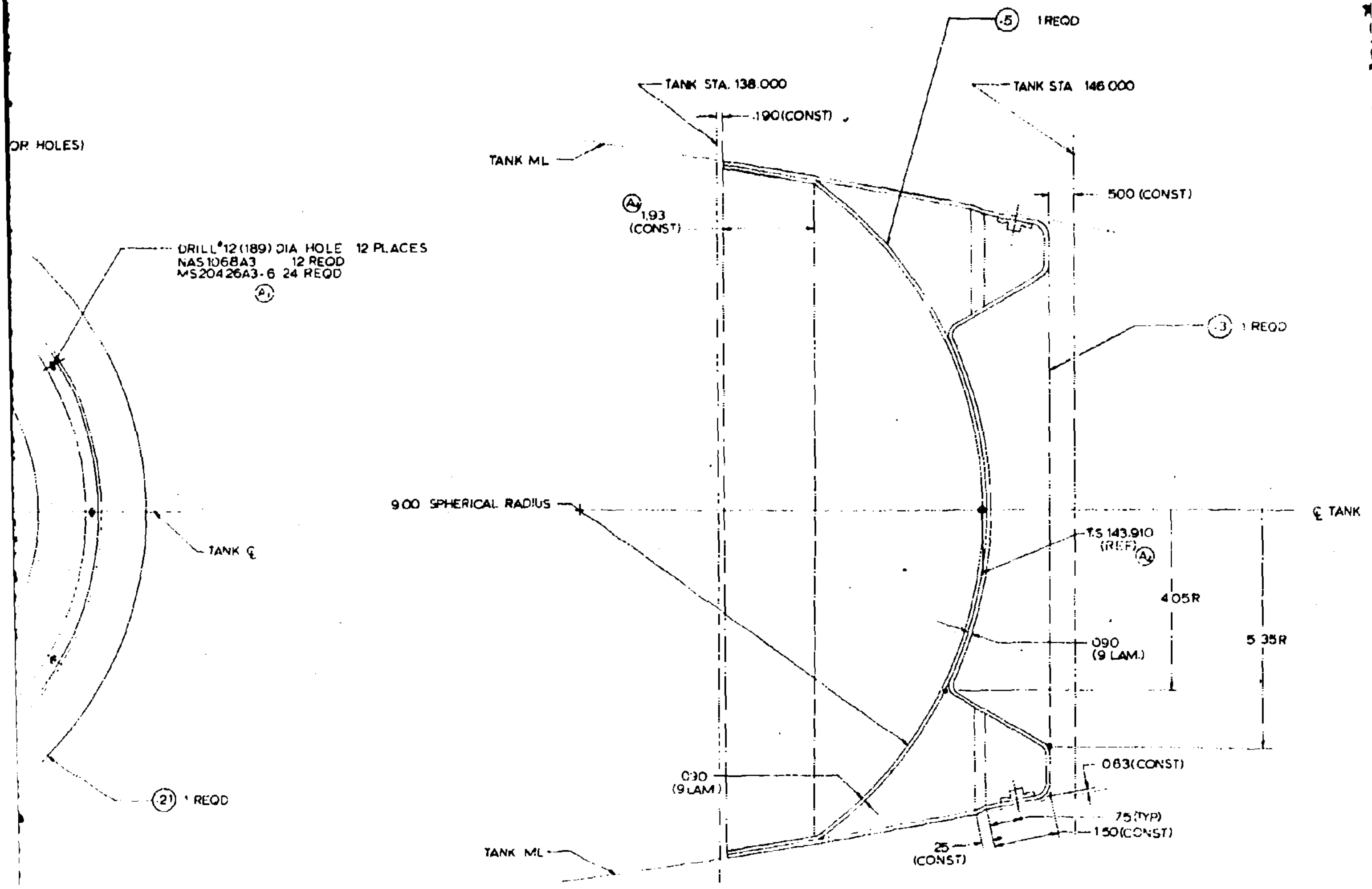
14	13	12	11	10



DETAIL OF -1 ASSY
(VIEW LOOKING FWD AT
AFT END OF PART)

14	13	12	11	10

10	9	8	7	6	5



SECTION A-A
(VIEW LOOKING OUTBD)
DETAIL -1 ASSY

6 WARP YARN DIRECTION OPTIONAL
5 INSTALL RIVETS PER SPEC LA0101-004
4 IDENTIFY PER NR SPEC STO 605HA C012 (TAG C
3 BEND RADIUS EQUALS .25
2 FOR CONTOURS & BEVELS SEE MD NOR 62-8
1 FABRICATE PER NR SPEC STO 605 HA 0018
NOTES UNLESS OTHERWISE NOTED

11-17907

10	9	8	7	6	5

1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
		1 MAY BE REWORKED 3 RECORD CHANGE 2 CANNOT BE REWORKED 4 NON INTERCHANGEABLE		
9 21	A	1- MS20426-A3-... WAS MS20426 ...		
10 6		2- ...		
10		3- ...		
8		4- ...		
		5- ITEM ON'S ... -11 TO -31 WITH ... PER SPEC HA 0105-055		
5		6- ADD ON'S INSTALL RIVETS PER SPEC LA 0101-004		
5C		7- MIL-C-9084 TYPE VIII WAS MB 0135-004 ...		
		8- FABRICATE PER SPEC STD 605HA 0001 (WAS) FABRICATE PER SPEC		
		11- IDENTIFY PER SPEC STD 605HA 0012 (TAG ONLY) (WAS) IDENTIFY PER ... LA 0... 001 (TAG ONLY)		

(3) 1 REQD

℄ TANK

5.35R

ITEM OR FIND NO			QUANTITY REQUIRED -31	-21	-11	-1	CODE IDENT	PART OR IDENTIFYING NUMBER	NOMENCLATURE	MATERIAL			SIZE	DRAWING OR SPECIFICATION NUMBER	ZONE
037															
036															
035															
034															
033															
032															
031															
030															
029															
028															
027															
026															
025															
024															
023															
022															
021															
020															
019															
018															
017															
016															
015															
014															
013															
012															
011															
010															
(A) 009			16	24				MS20426A3-6	RIVET						9/21
008			8	12				NAS1068A3	NUTPLATE						9/21
007					1			-31	SUB ASSY						21
006						1		-21	SUB ASSY						10
(A) 005					1			-15	PAN	181E" GLASS FABRIC	—	—	4.3 sq ft	MIL-C-9084 TYPE VIII	18
(A) 004			1					-13	RING		—	—	4.5 sq ft		18
(A) 003						1		-5	PAN		—	—	19.0 sq ft		6
(A) 002				1				-3	RING	181E GLASS FABRIC	—	—	3.40 sq ft	MIL-C-9084 TYPE VIII	5
001								TT-17907	BOLTING RING A.O.						

PARTS LIST

ITEM	QTY REQD PER END ITEM	MODEL	NEXT USING DRAWING	END ITEM NO EFFECTIVE	THRU ON
-11	1	SO4188	TT-17901		
-1	1	SO4188	TT-17901		

APPLICATION (USAGE) DATA

HEAT TREAT NONE

FINISH NONE

INSPECT PER ... (10000) ODF CLASS II

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. DO NOT SCALE PRINT

CONTR NO

COLUMBUS DIVISION NORTH AMERICAN ROCKWELL CORPORATION COLUMBUS, OHIO 43216

BOLTING RING - COLLAPSIBLE WING TANK, ASSY OF (TEST)

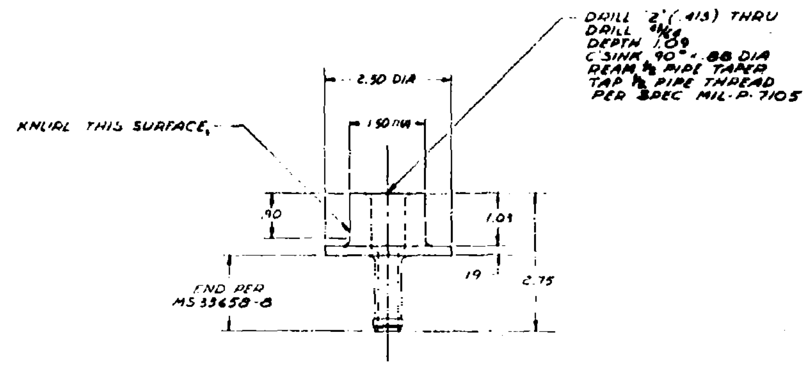
SIZE J CODE IDENT NO 89372 TT-17907

SCALE SHEET

...ION OPTIONAL
...ER SPEC LA 0101-004
...EC STD 605HA 0012 (TAG ONLY)
...ENTS SEE MDNOR 62-82
...SPEC STD 605HA 0012
...NOTED

FORM 311 G4 REV 5-67

Figure 55 Bolting Ring and Pan (Fwd. and Aft)



4. $\sqrt{}$ ALL MACHINED SURFACES.
3. MACHINE R = .125
2. IDENTIFY PER NR SPEC LA0104-003 EXCEPT DO NOT METAL IMPRESSION STAMP.
1. MACHINE PER NR SPEC LA0103-004.

NOTES: UNLESS OTHERWISE NOTED

3	1	SC 4100	TT-1902	

APPLICATION (USAGE) DATA

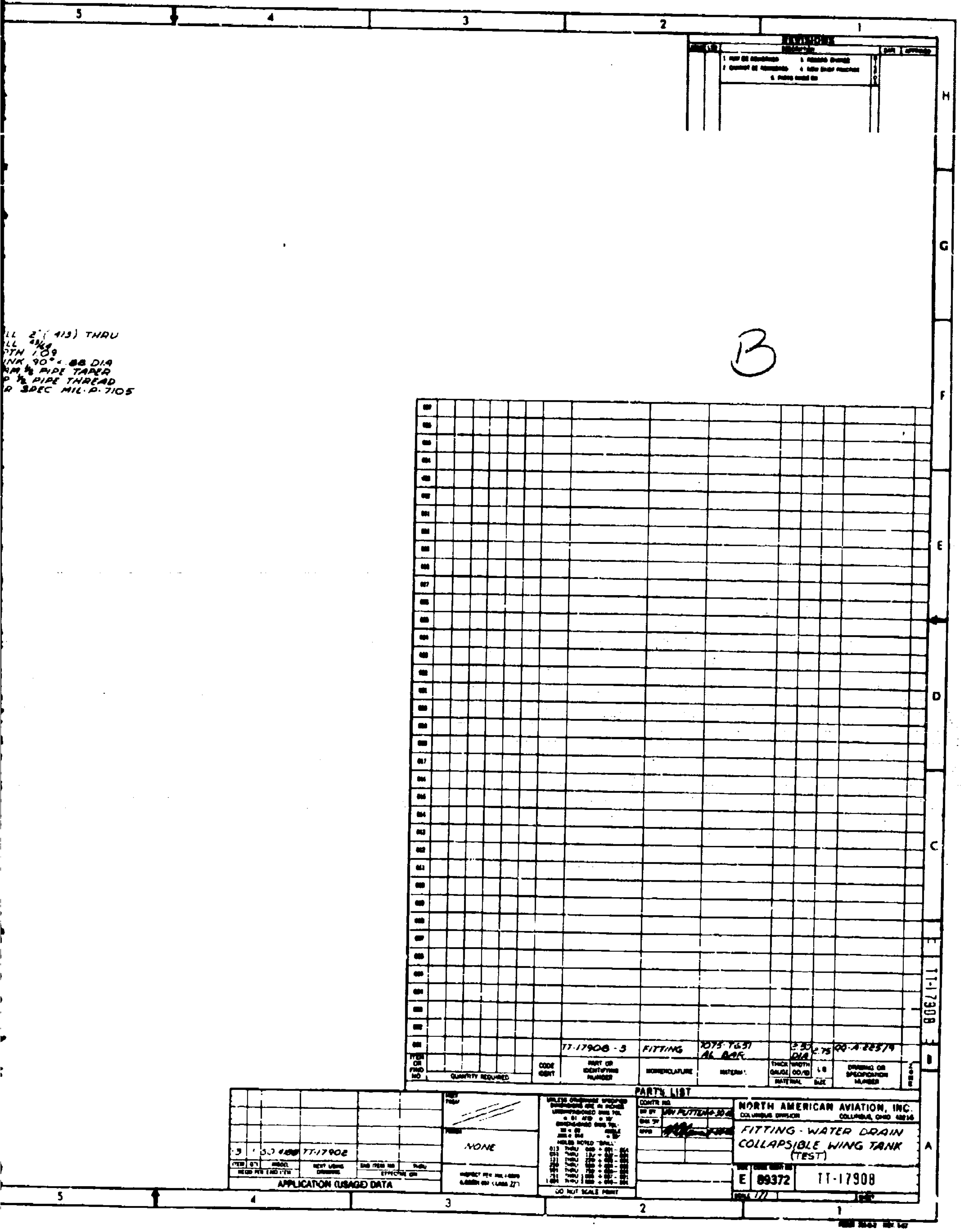
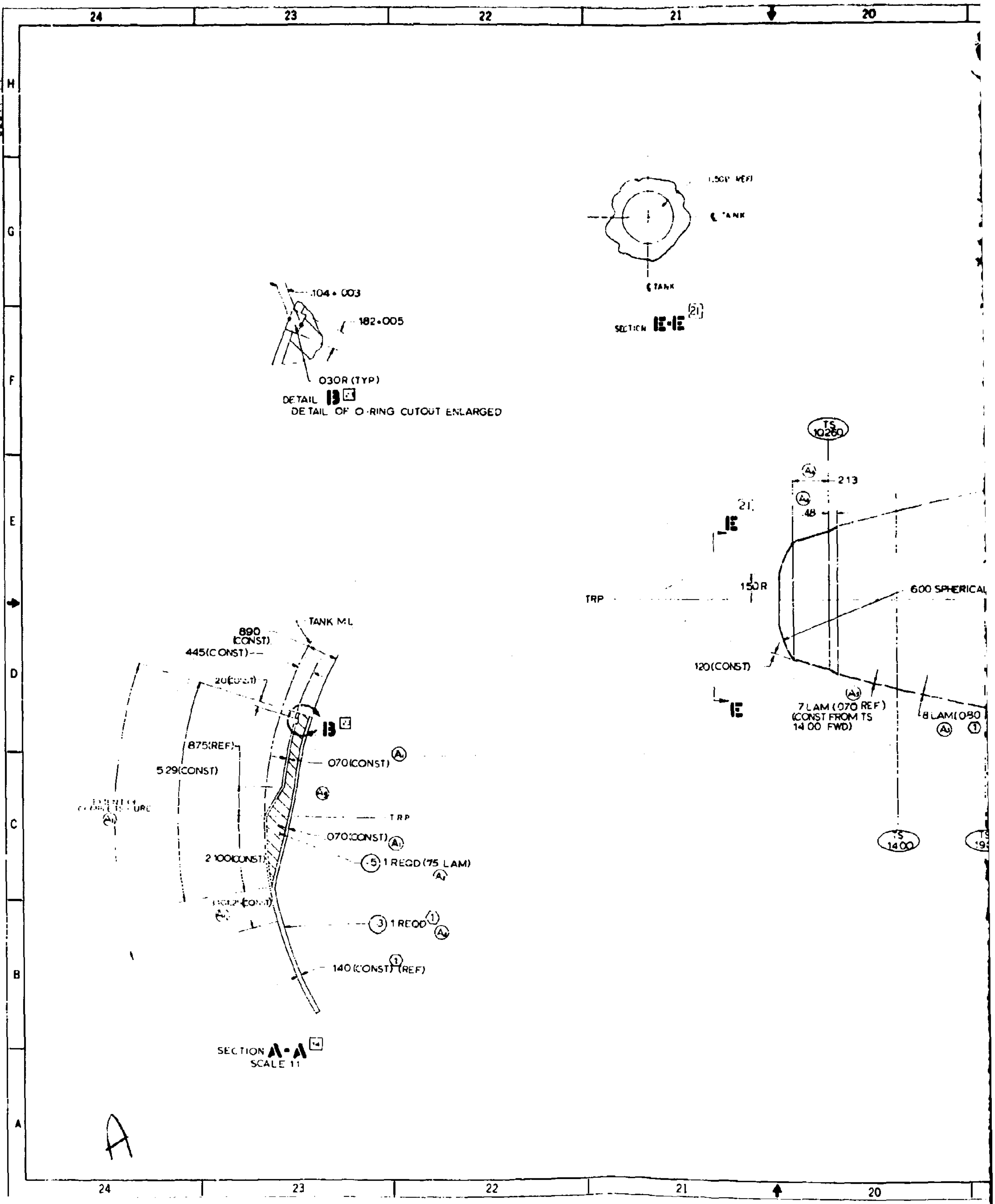
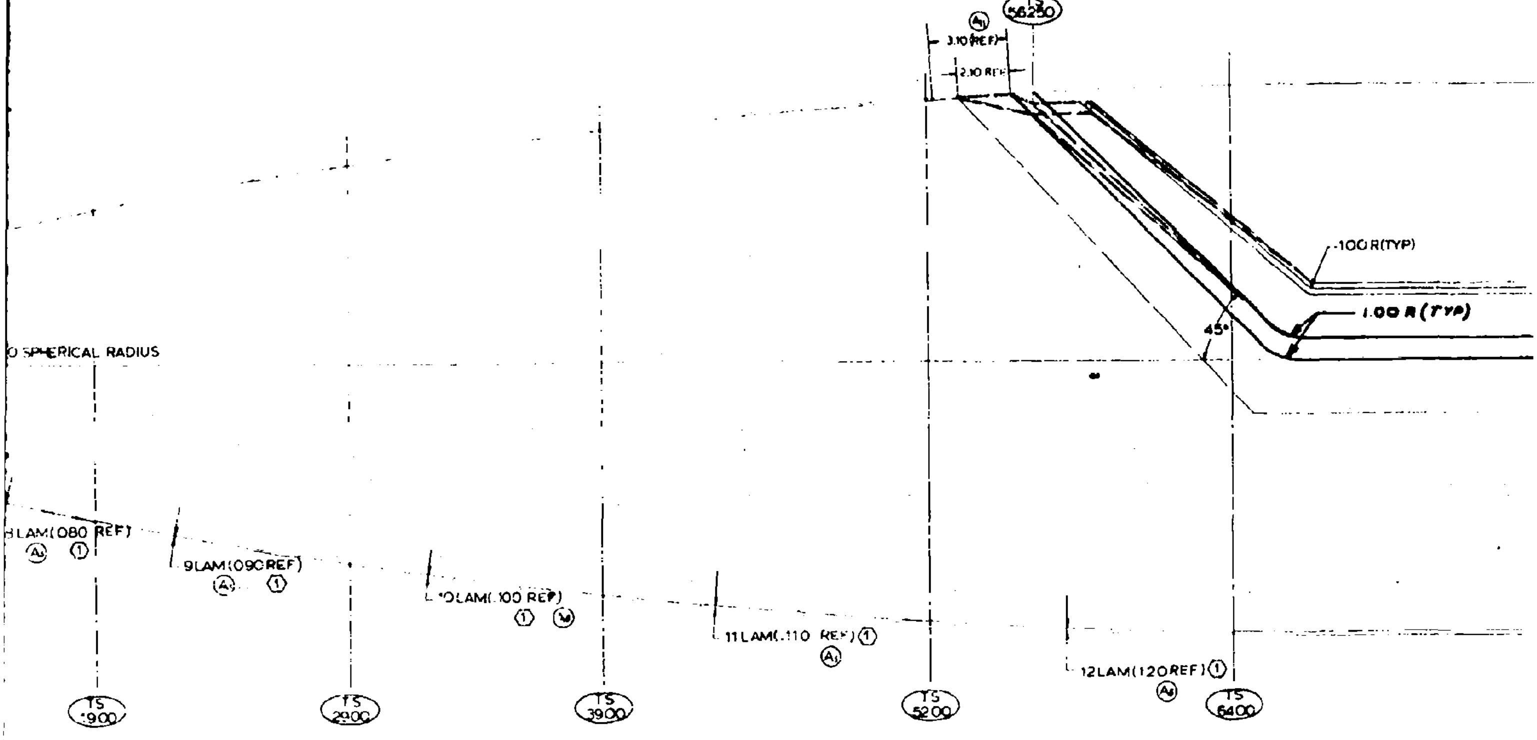


Figure 56 Water Drain Fitting



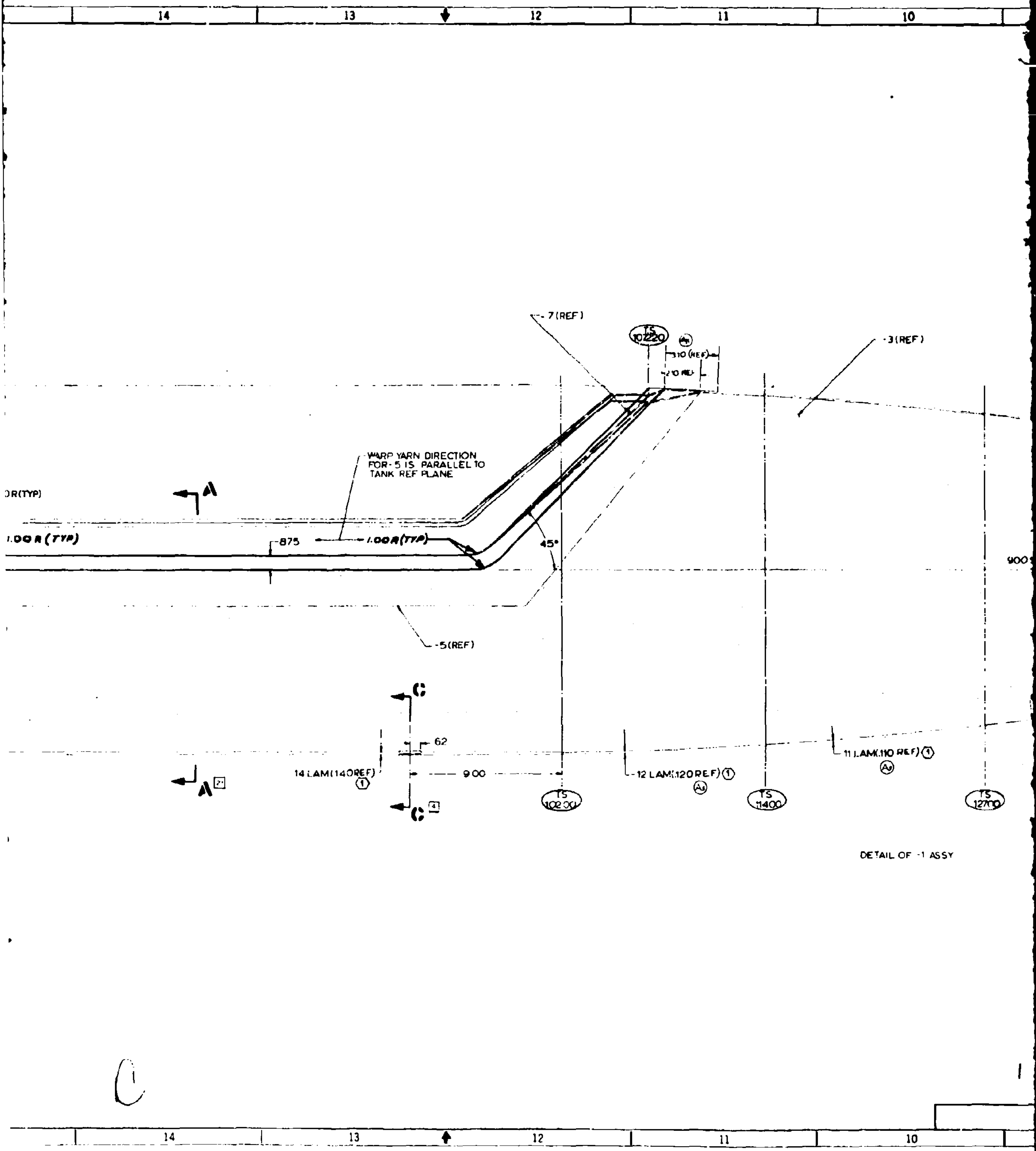
.104 ± .003
.182 ± .005
.030R (TYP)
DETAIL B
DETAIL OF O-RING CUTOUT ENLARGED
℄ TANK
℄ TANK
SECTION E-E
TS 10.260
.213
.48
E
.150R
TRP
.600 SPHERICAL
.120(CONST)
7 LAM (.070 REF)
(CONST FROM TS 14.00 FWD)
8 LAM(.080
E
TS 14.00
TANK ML
.890 (CONST)
.445(CONST)
B
.070(CONST)
.875(REF)
5.29(CONST)
TRP
.070(CONST)
2.100(CONST)
-5 1 REQD (75 LAM)
-3 1 REQD
.140 (CONST) (REF)
SECTION A-A
SCALE 1:1
A

19 18 17 16 15

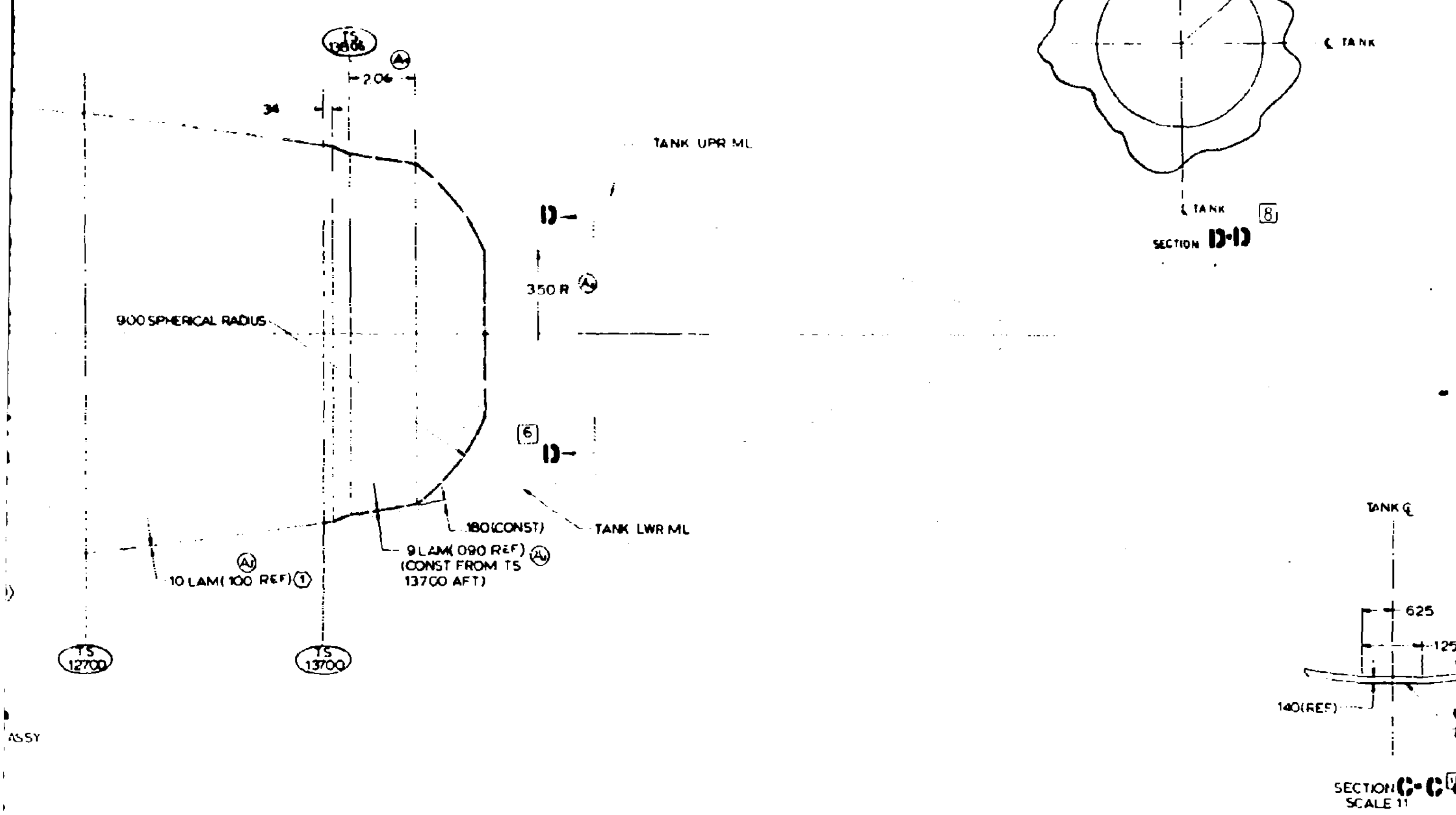


B

19 18 17 16 15



DETAIL OF -1 ASSY



8 CONST BET DIM STATIONS INDICATED ON LWR ML
7 IDENTIFY PER NR SPEC ST0605-0012
6 WARP YARN DIRECTION OPTIONAL
5 ALL MACHINED SURFACES TO BE √
4 MACHINE PER NR SPEC LA0103-004
3 BEND RADIUS EQUALS .25
2 FOR BEVELS & CONTOURS SEE MD NOR 62-82
1 FABRICATE PER NR SPEC ST0605-0012
NOTES UNLESS OTHERWISE NOTED

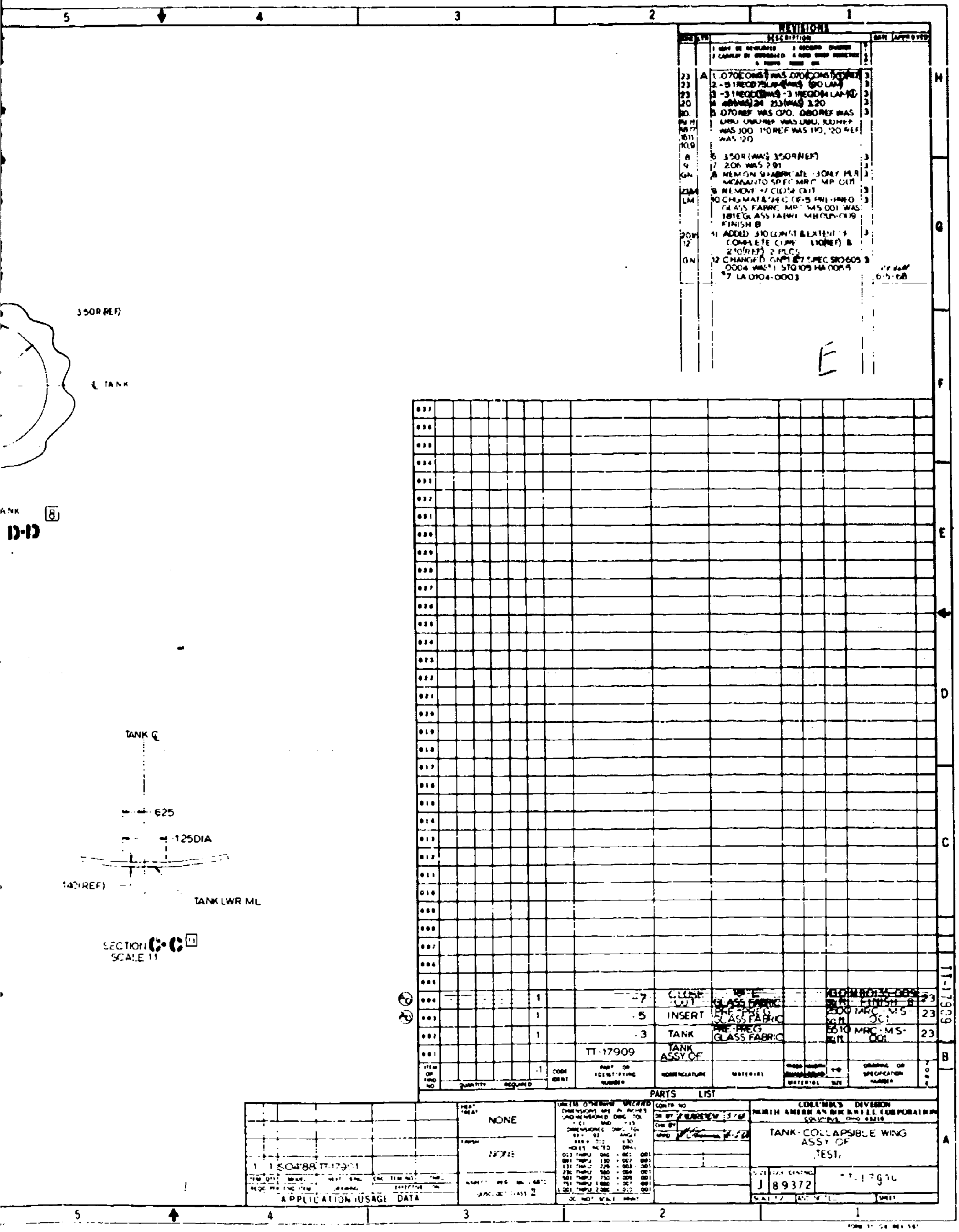


Figure 57 Buckling Coefficient of Hydrostatic Pressure

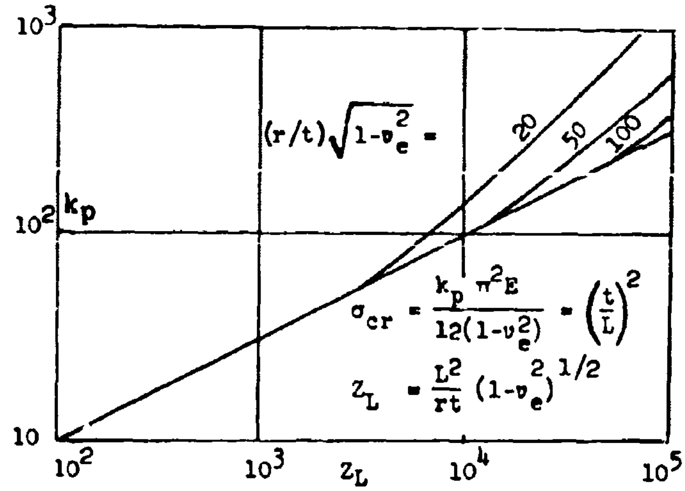


Figure 58 Buckling Coefficient of Hydrostatic Pressure

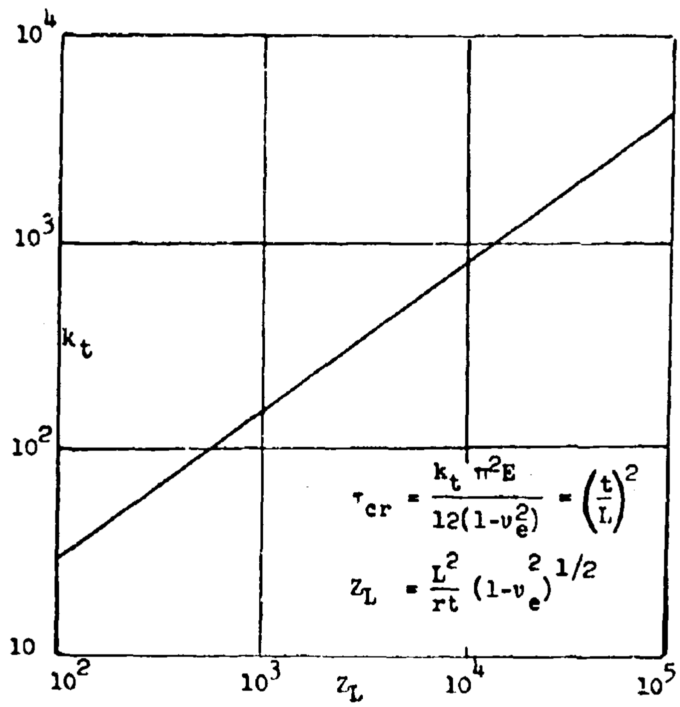


Figure 59 Buckling Coefficient for Cylinder in Torsion

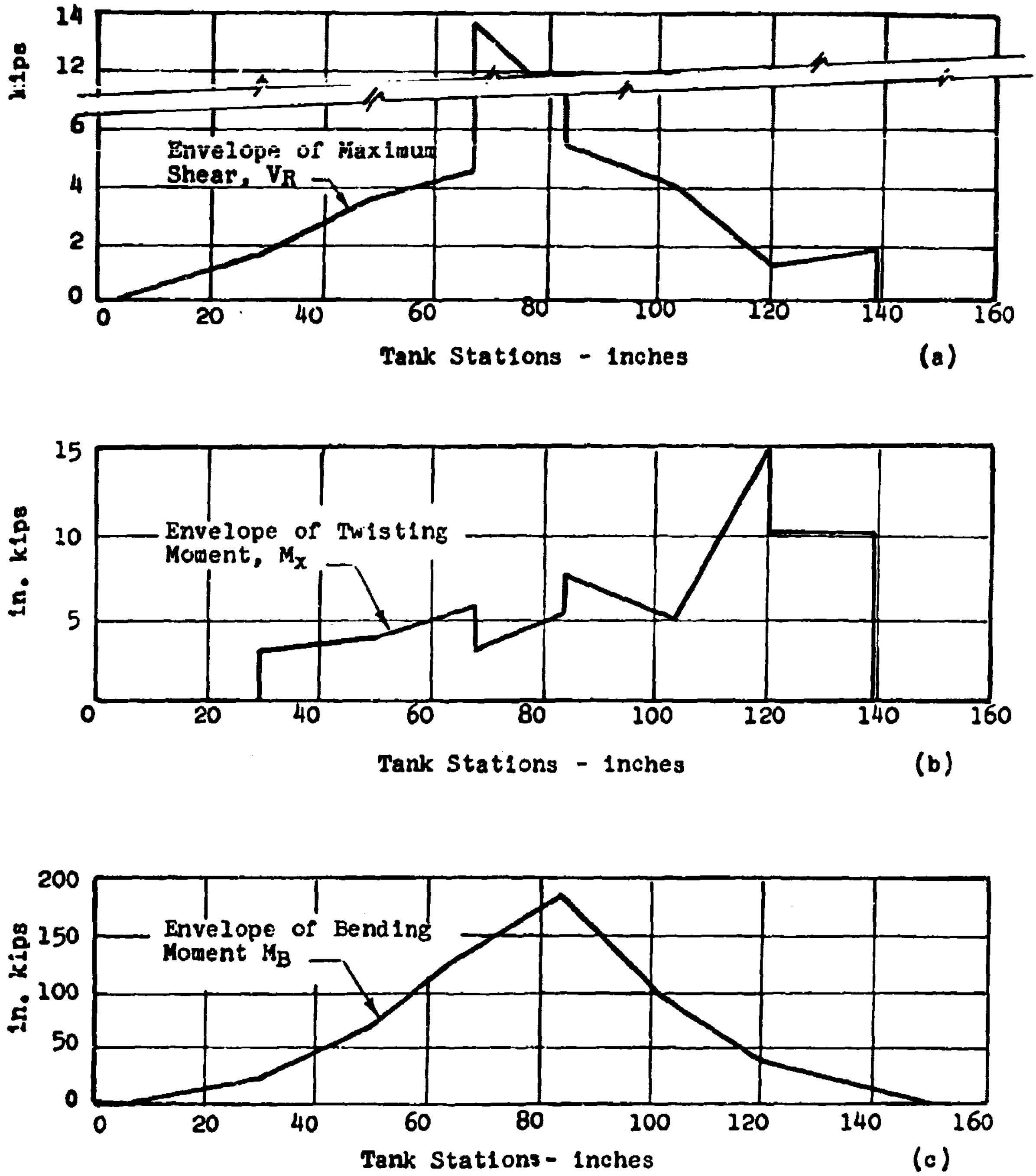
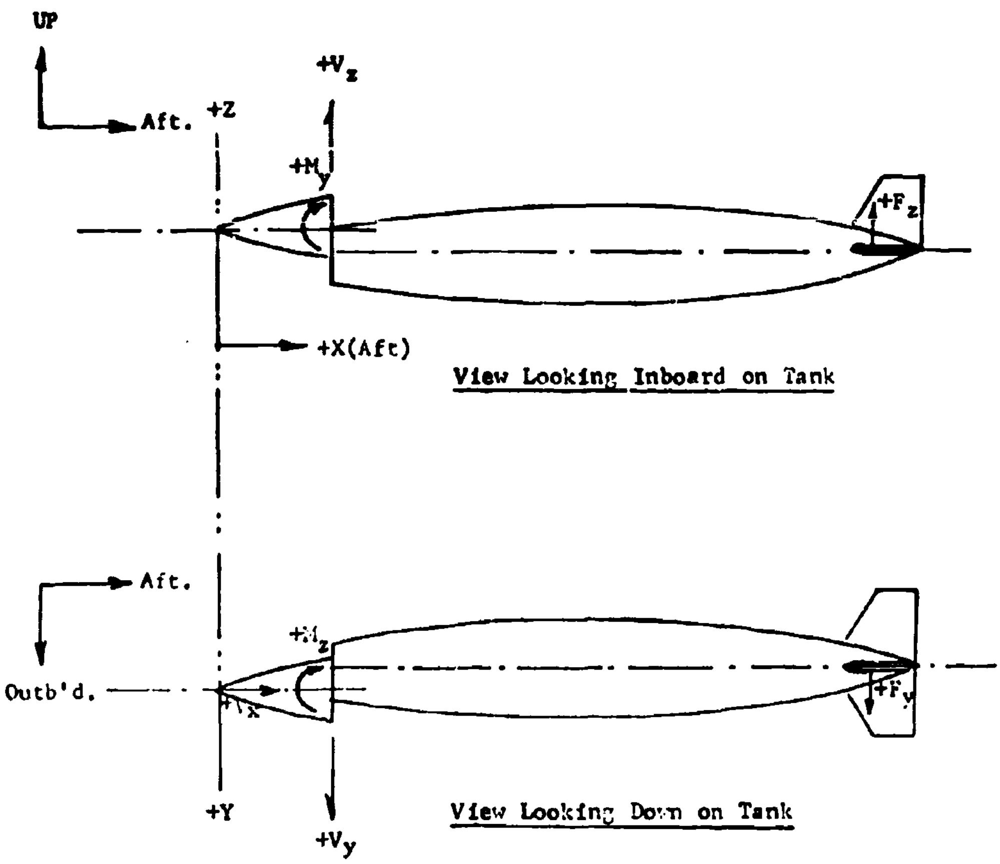


Figure 60 Maximum Envelopes of Tank Loads



$+V_x$ FWD FACE OF CUT COMPRESSES AFT FACE
$+V_y$ FWD FACE OF CUT PULLS OUTBOARD ON AFT FACE
$+V_z$ FWD FACE OF CUT PULLS UP ON AFT FACE

$+M_x$ COUNTERCLOCKWISE LOOKING AFT
$+M_y$ NOSE UP MOMENT, (COMPRESSION IN UPPER TANK SKIN)
$+M_z$ NOSE RIGHT MOMENT, (COMPRESSION ON INBOARD TANK SKIN)

$+F_y$ OUTBOARD FIN LOAD
$+F_z$ UP FIN LOAD

Figure 61 - Stress Analysis Sign Convention

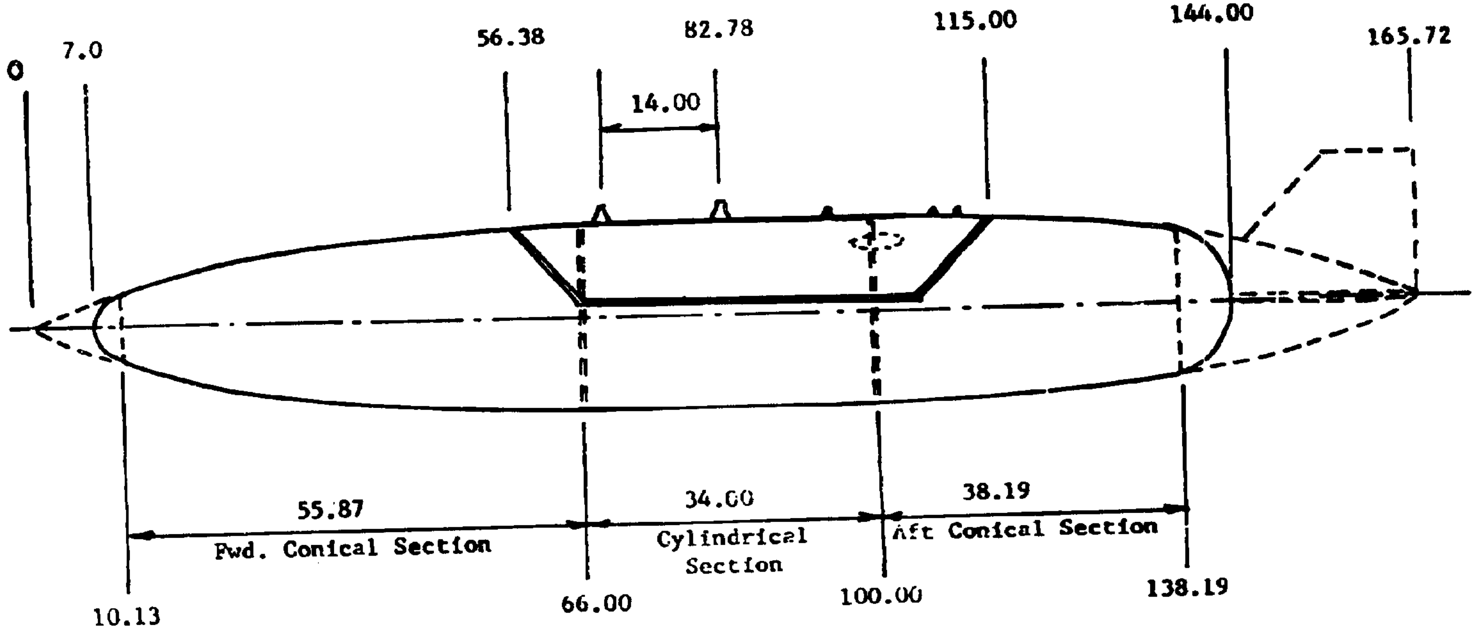
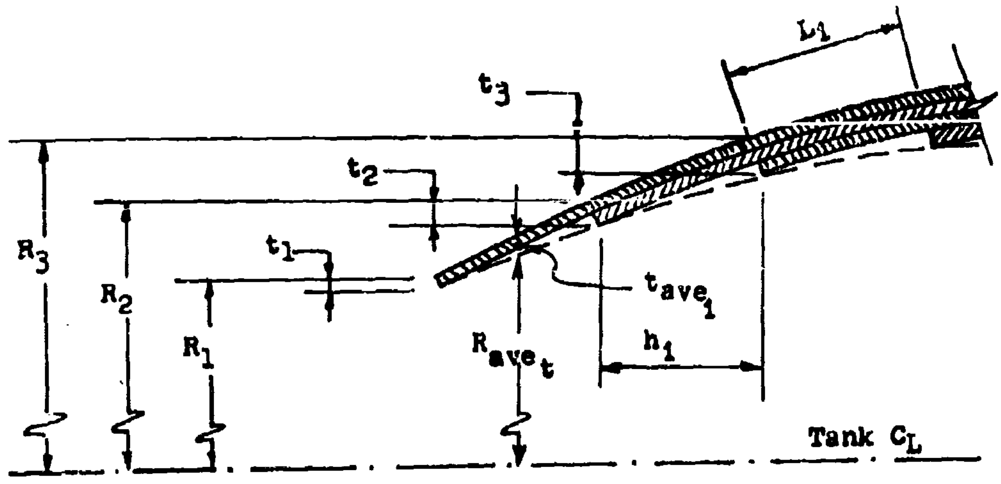


Figure 62 Tank Schematic for Shell Weight Calculations



$$R_i' = R_i - \tfrac{1}{2}t_i$$

$$L_i = \sqrt{(R_{i+1}' - R_i')^2 + h_i^2}$$

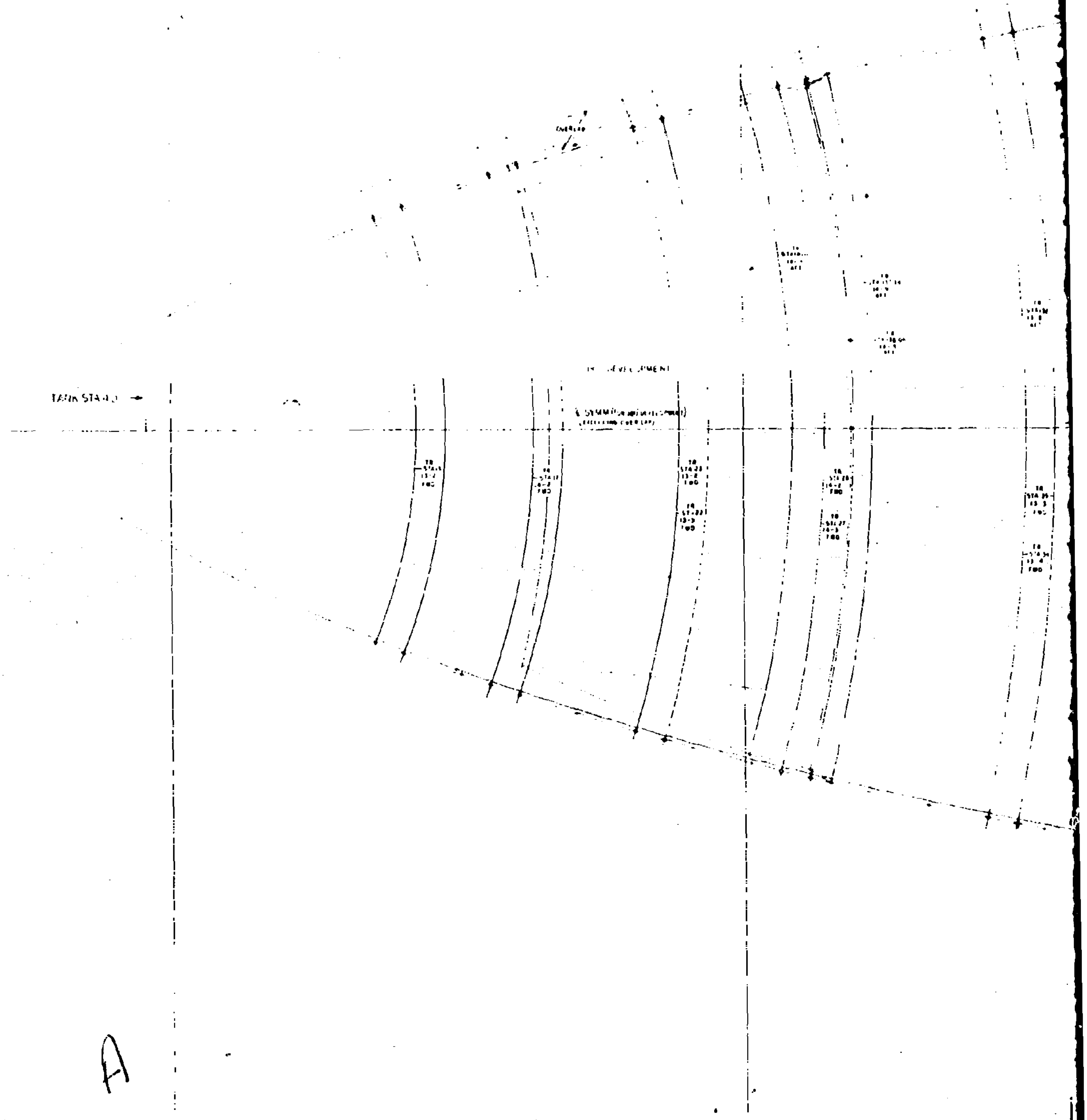
$$t_{ave_i} = \tfrac{1}{2}(t_i + t_{i+1})$$

$$R_{ave_i} = \tfrac{1}{2}(R_i' + R_{i+1}')$$

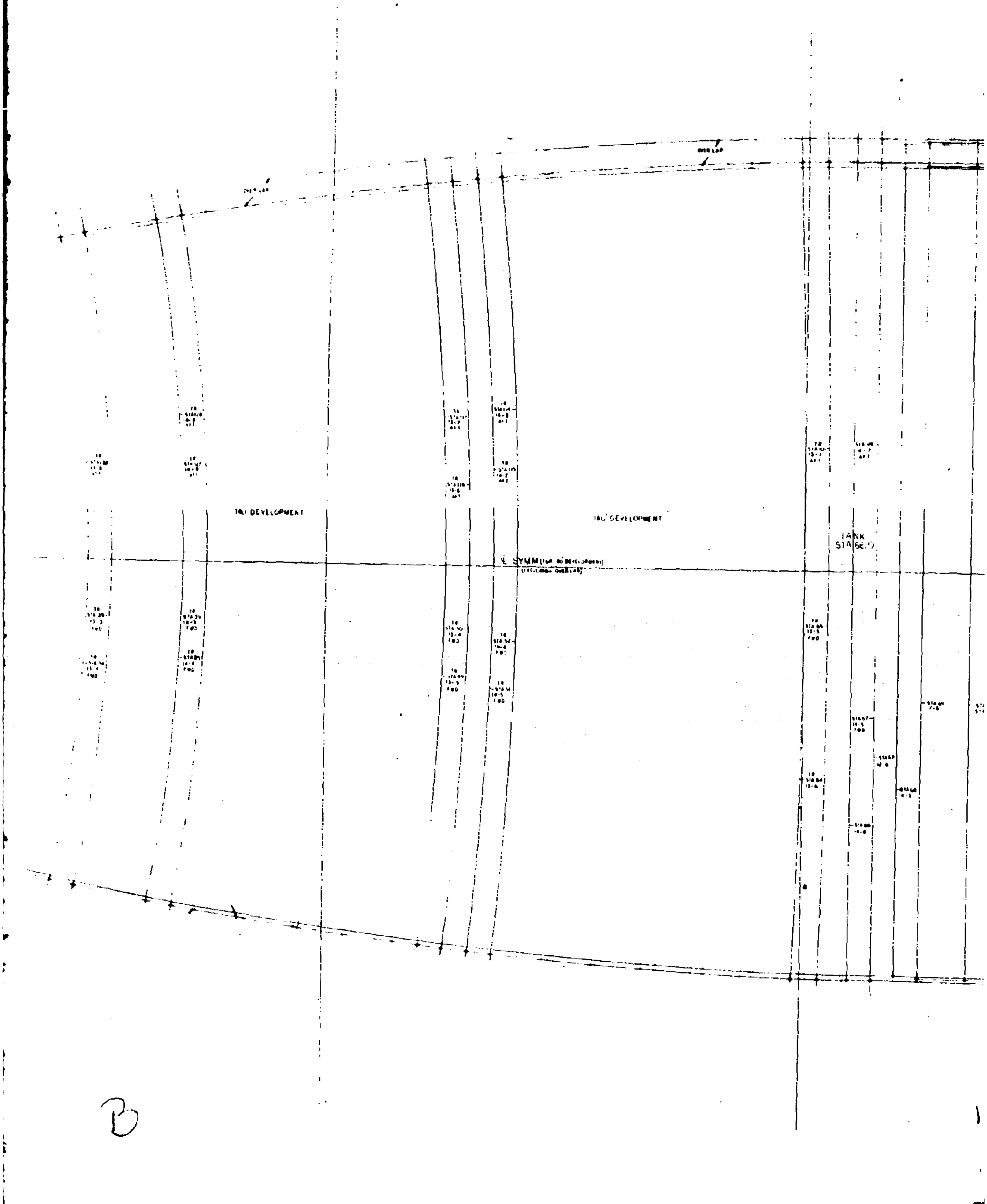
$$\text{Shell Volume} = 2\pi(R_{ave_i})(t_{ave_i})(L_i)(\rho)$$

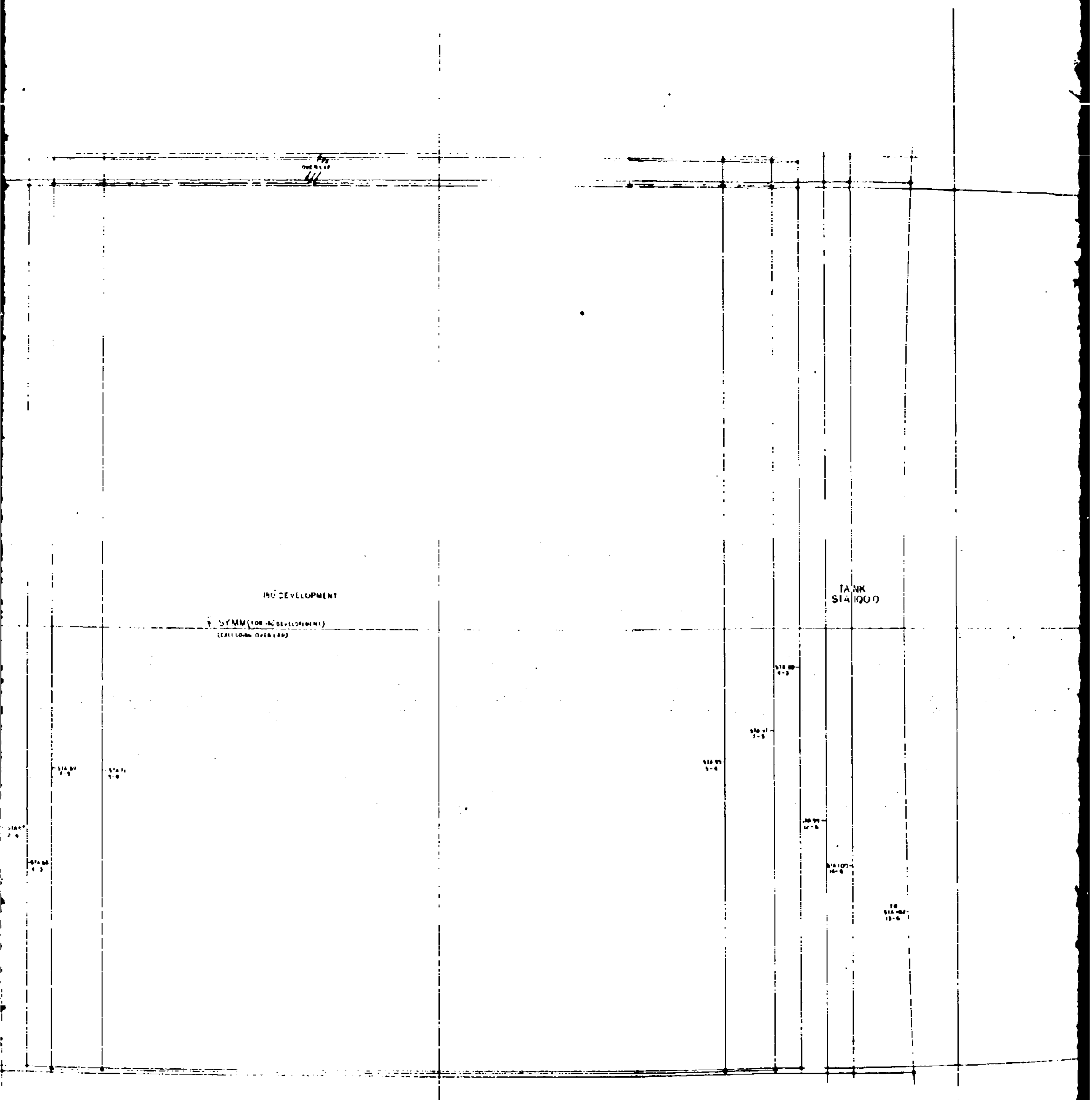
$$\text{Tank Volume} = \frac{1}{3}\left[A_i + A_{i+1} + \sqrt{(A_i)(A_{i+1})}\right]h_i$$

Figure 63 Method of Approximating Shell Weight and Volume



A


OVERLAP
OVERLAP
180° DEVELOPMENT
180° DEVELOPMENT
TANK
STA 56.0
℄ SYMM
B

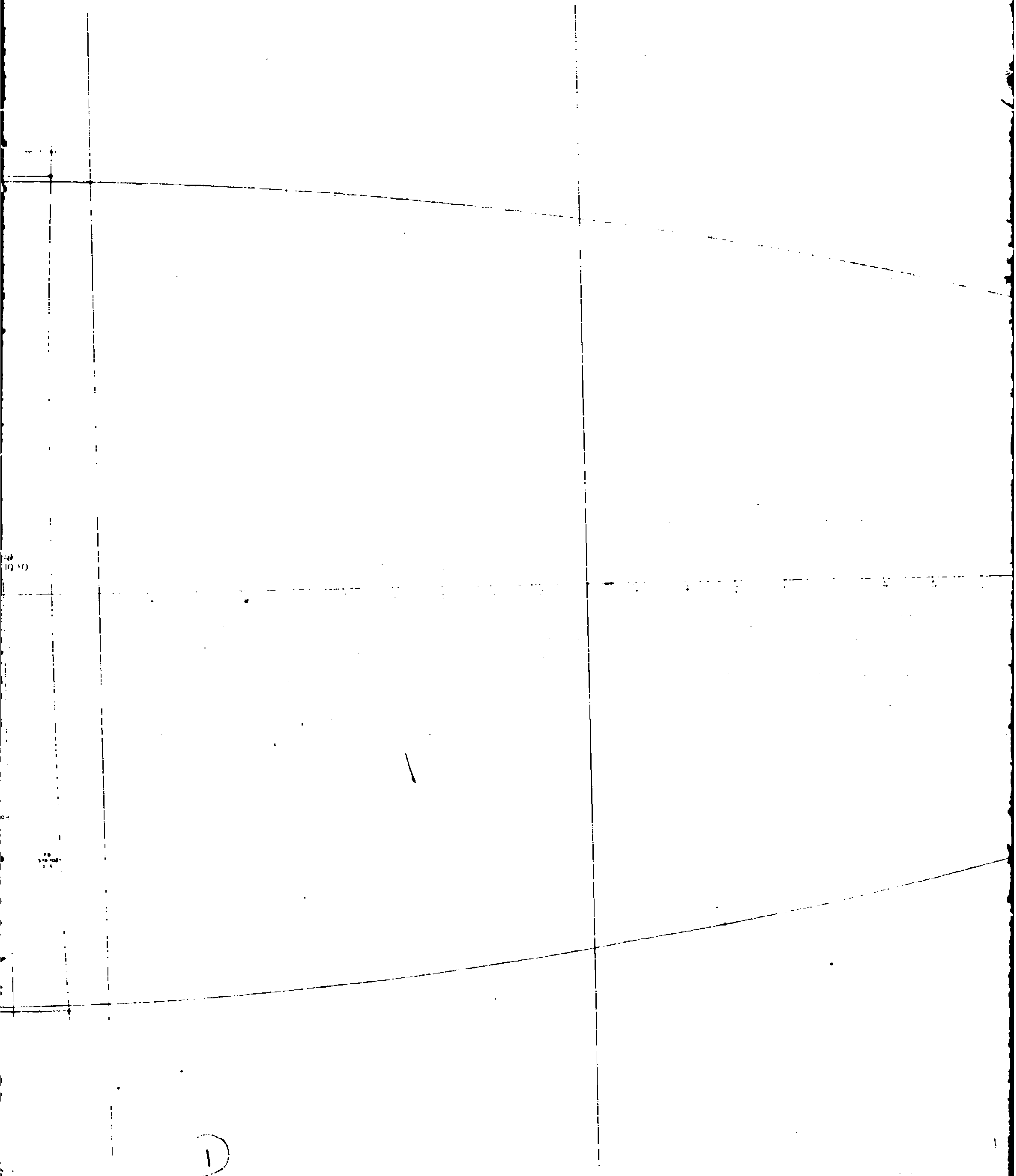


EXPANDABLE RIGIDIZABLE FUEL TANK

FLAT PATTERNS

SHEET 1 OF 4

C



1

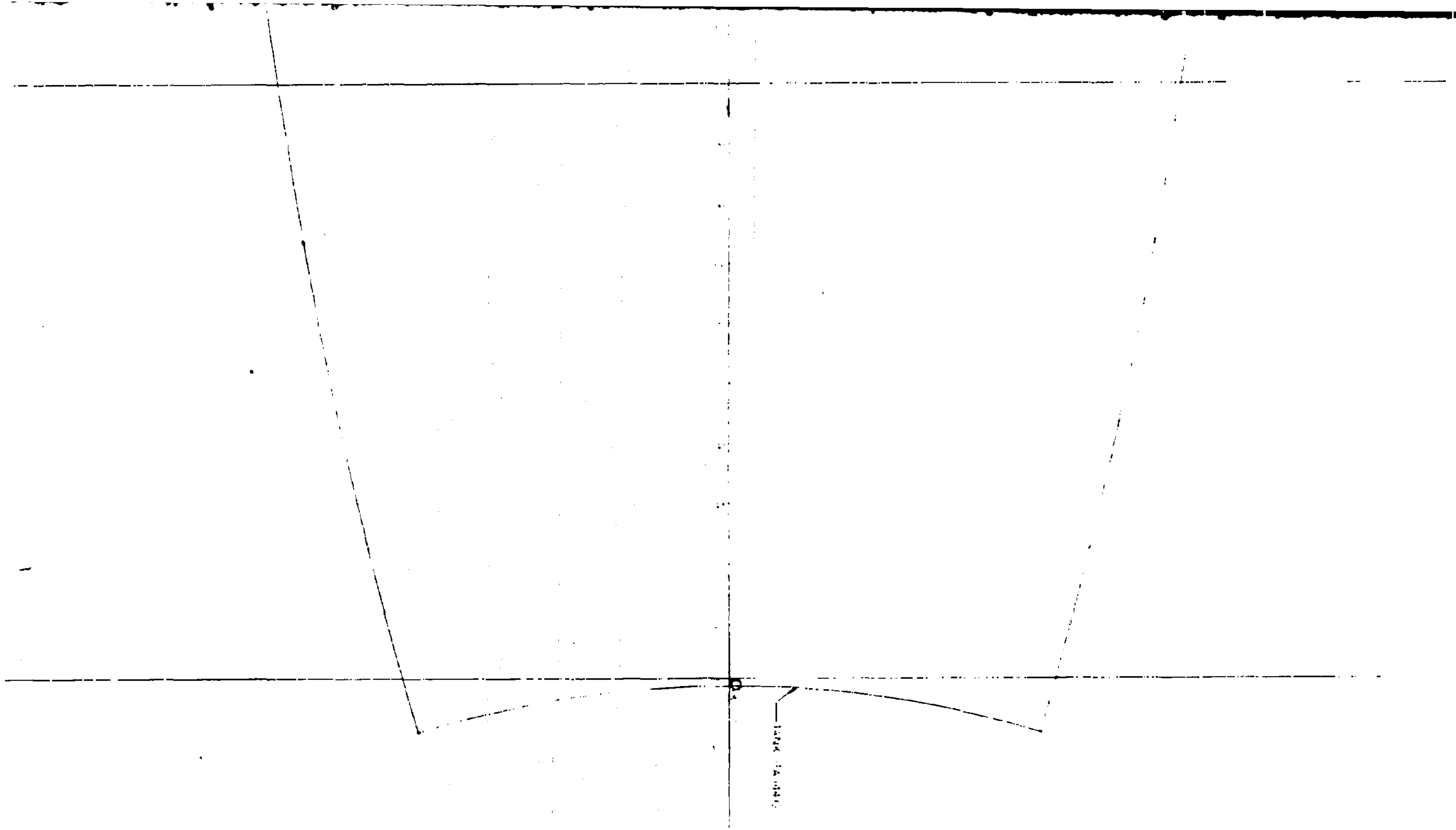
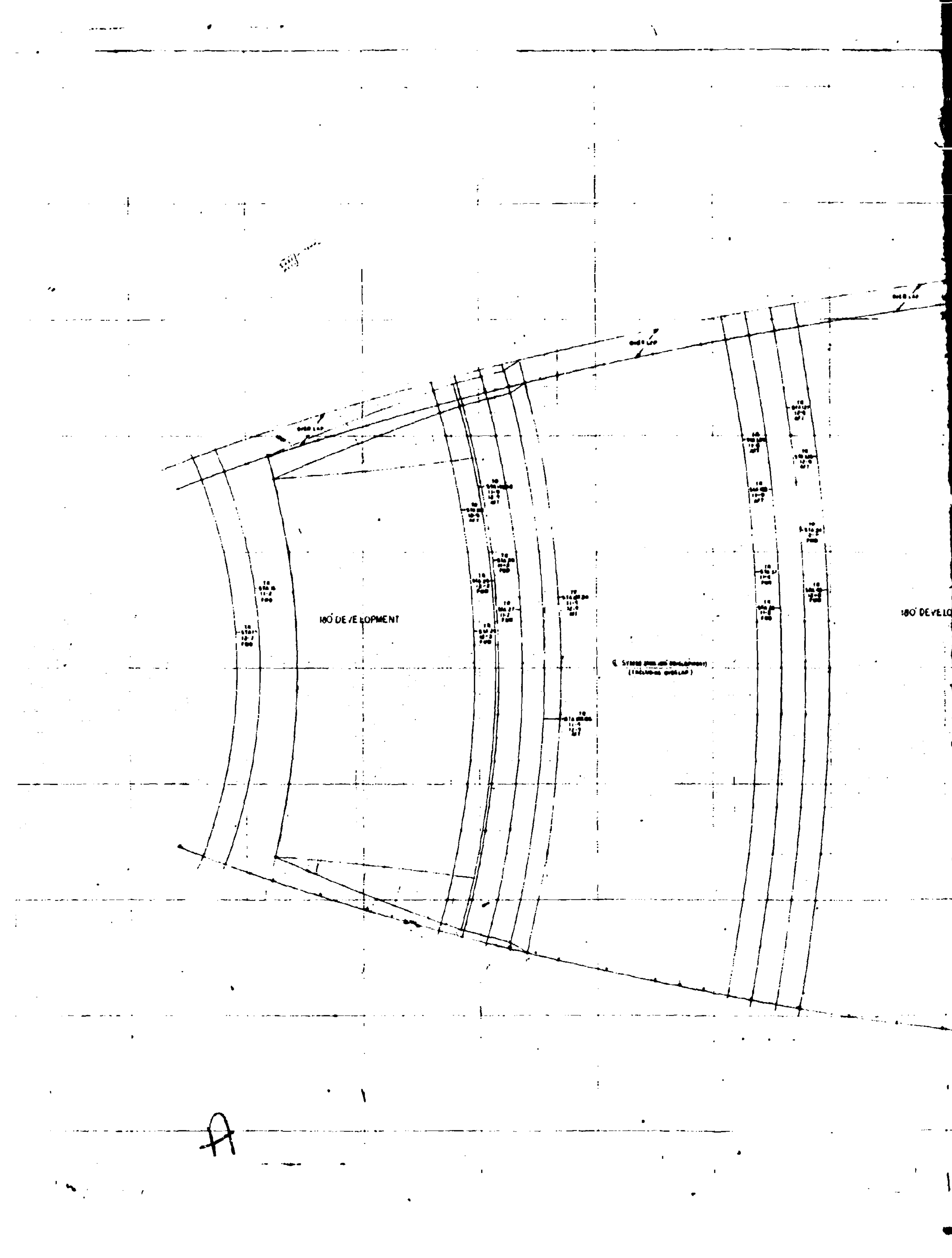
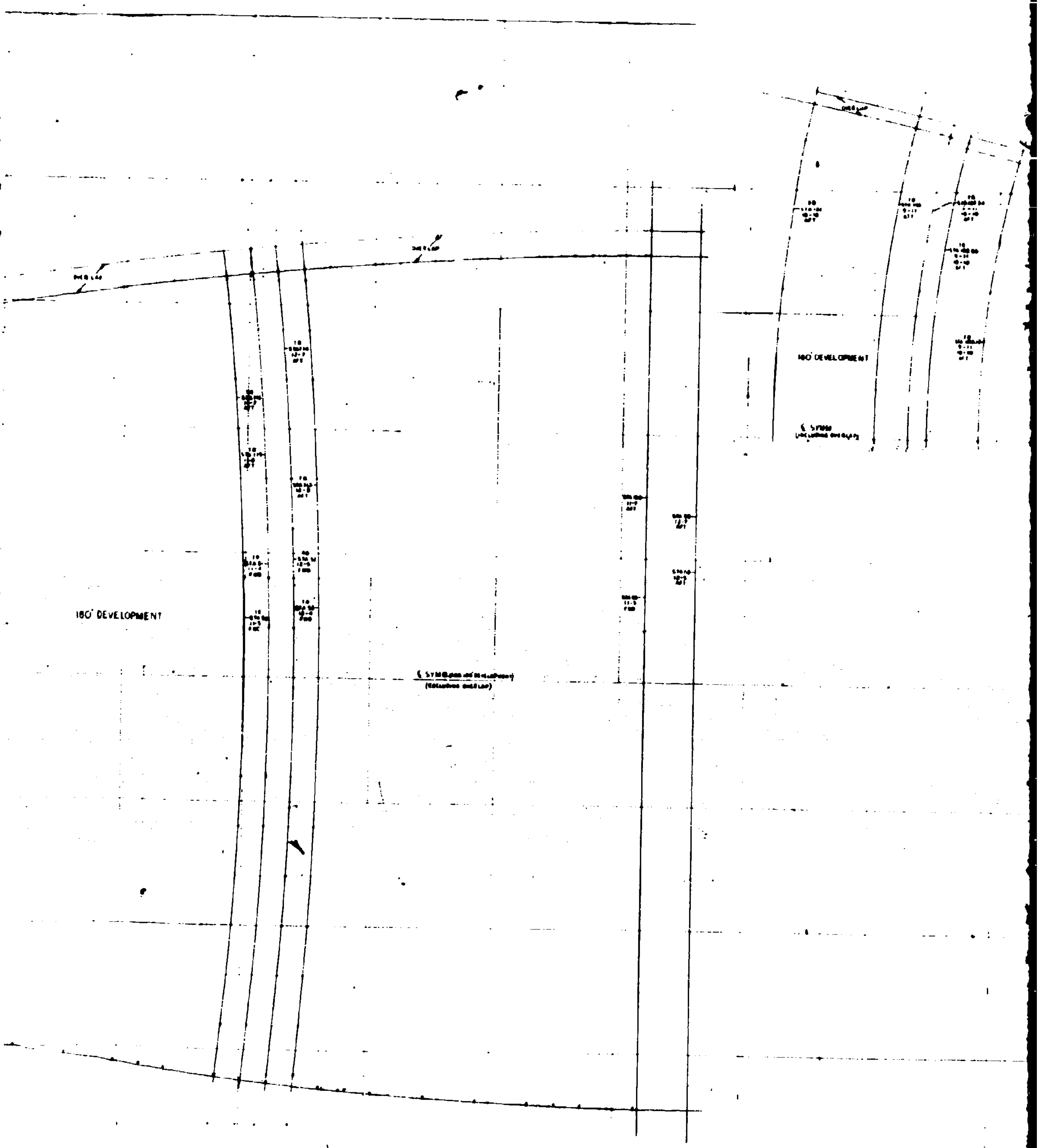


Figure 64 Flat Patterns of Developed Gores


180° DEVELOPMENT
180° DEVELO
A

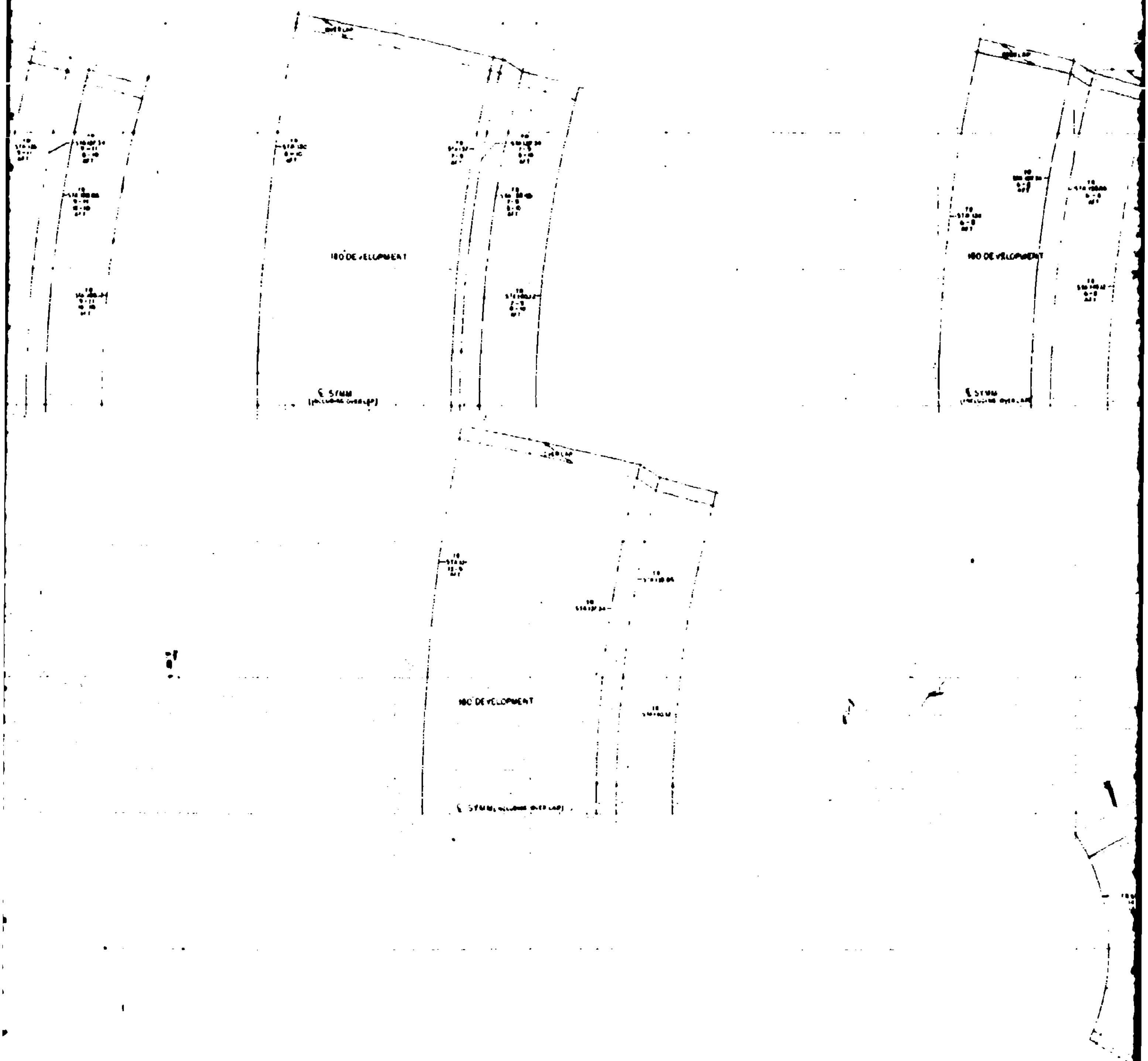


EXPANDABLE RIGIDIZABLE FUEL TANK

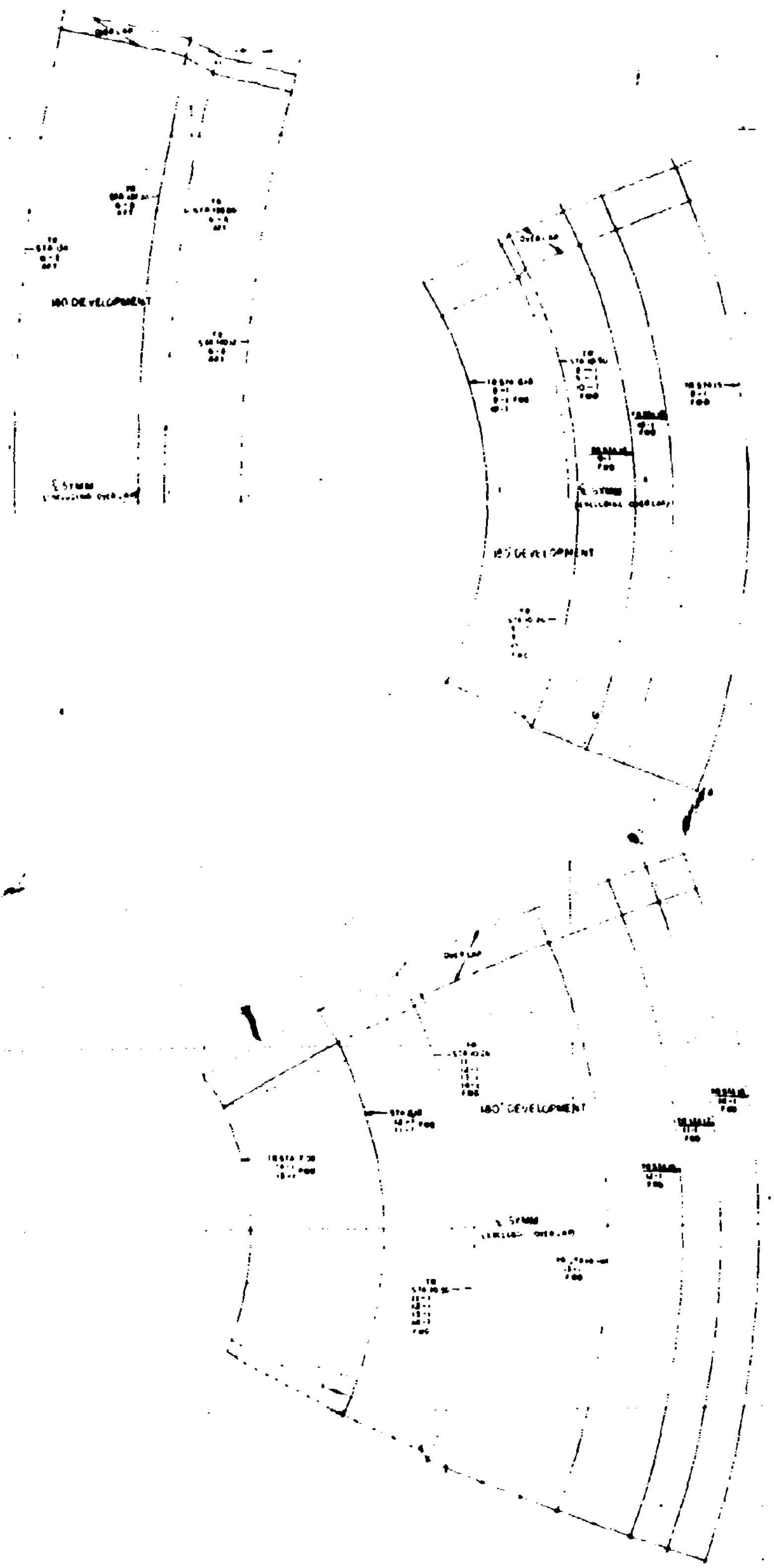
FLAT PATTERNS

SHEET 2 OF 4

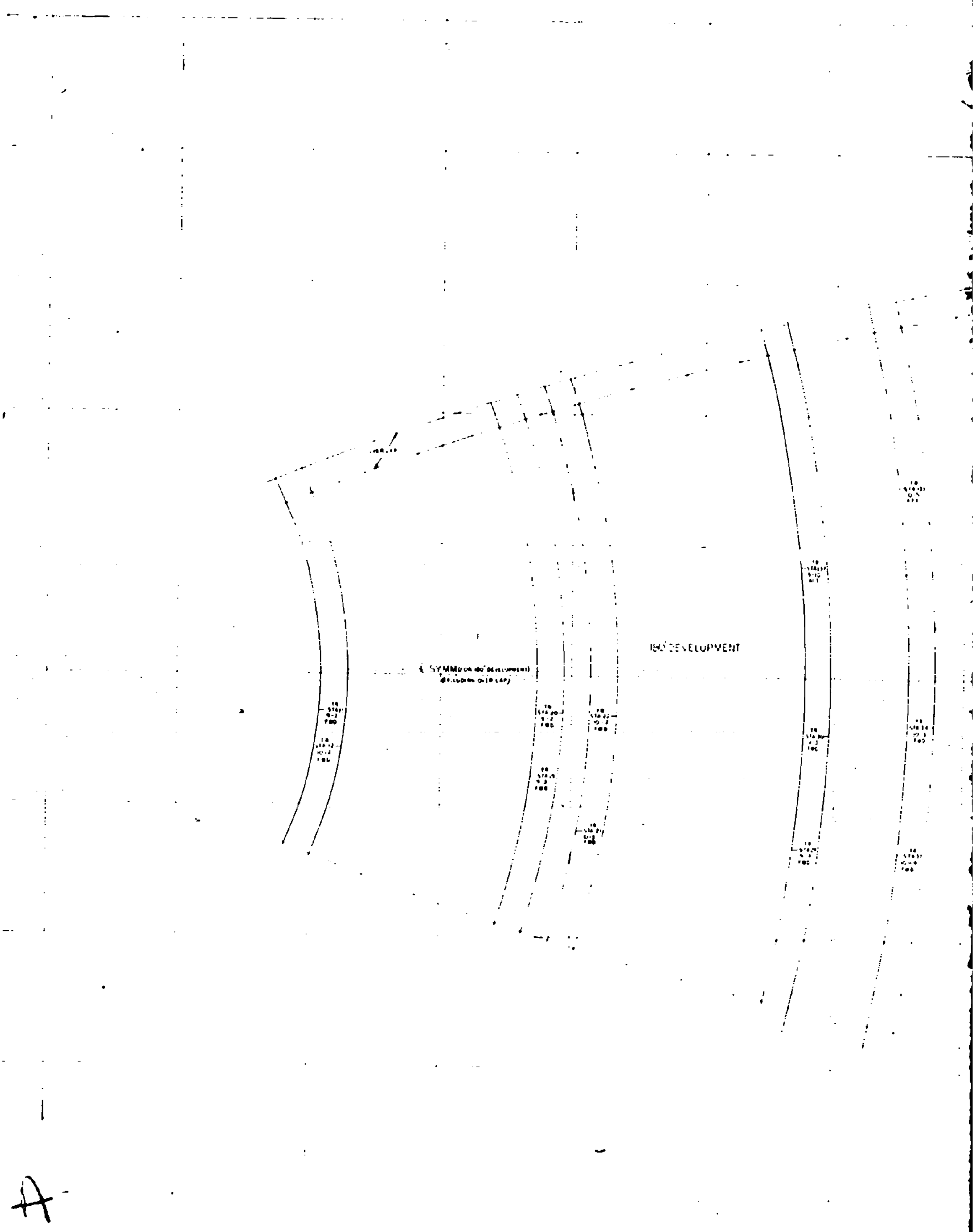
B

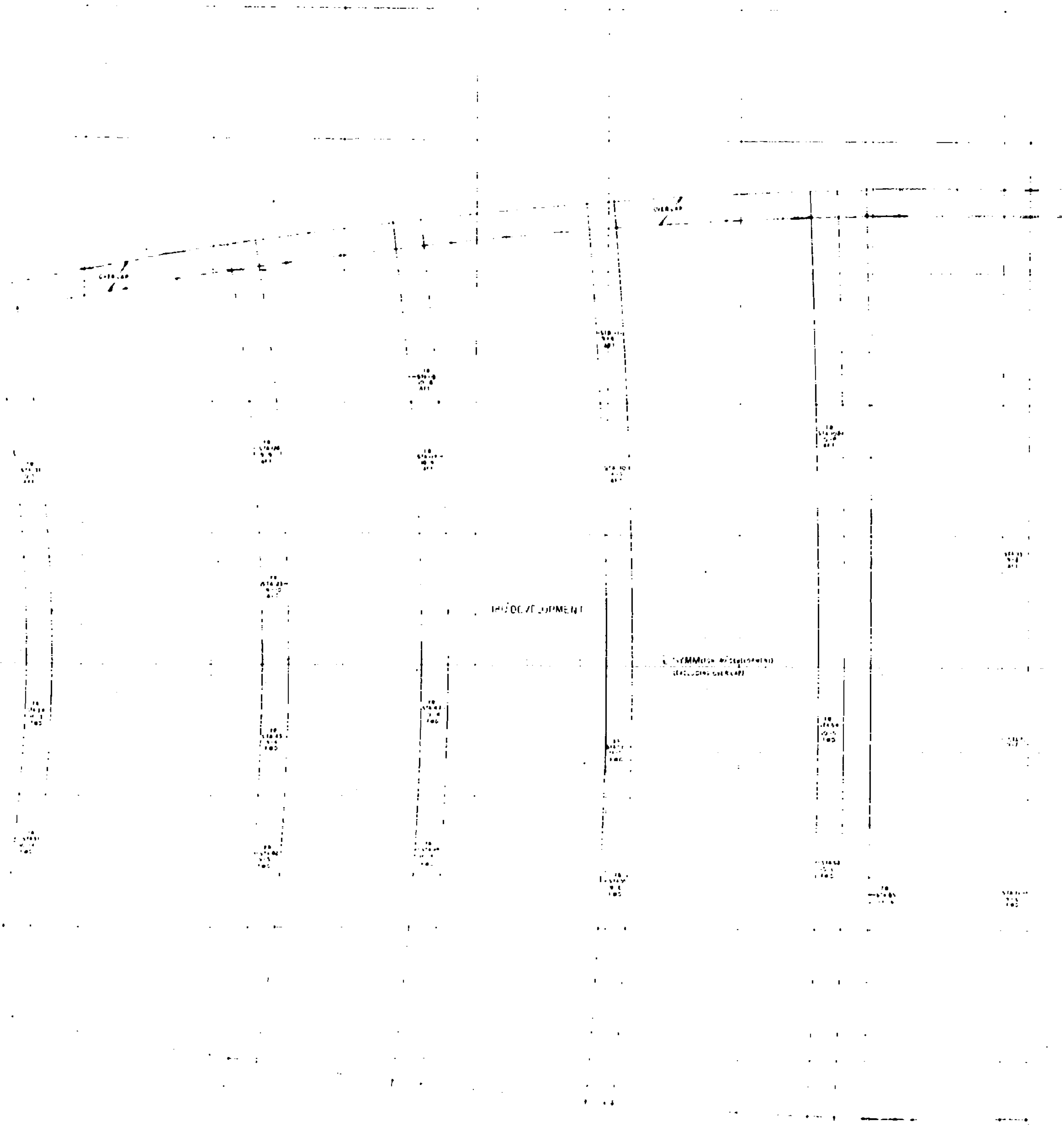


C



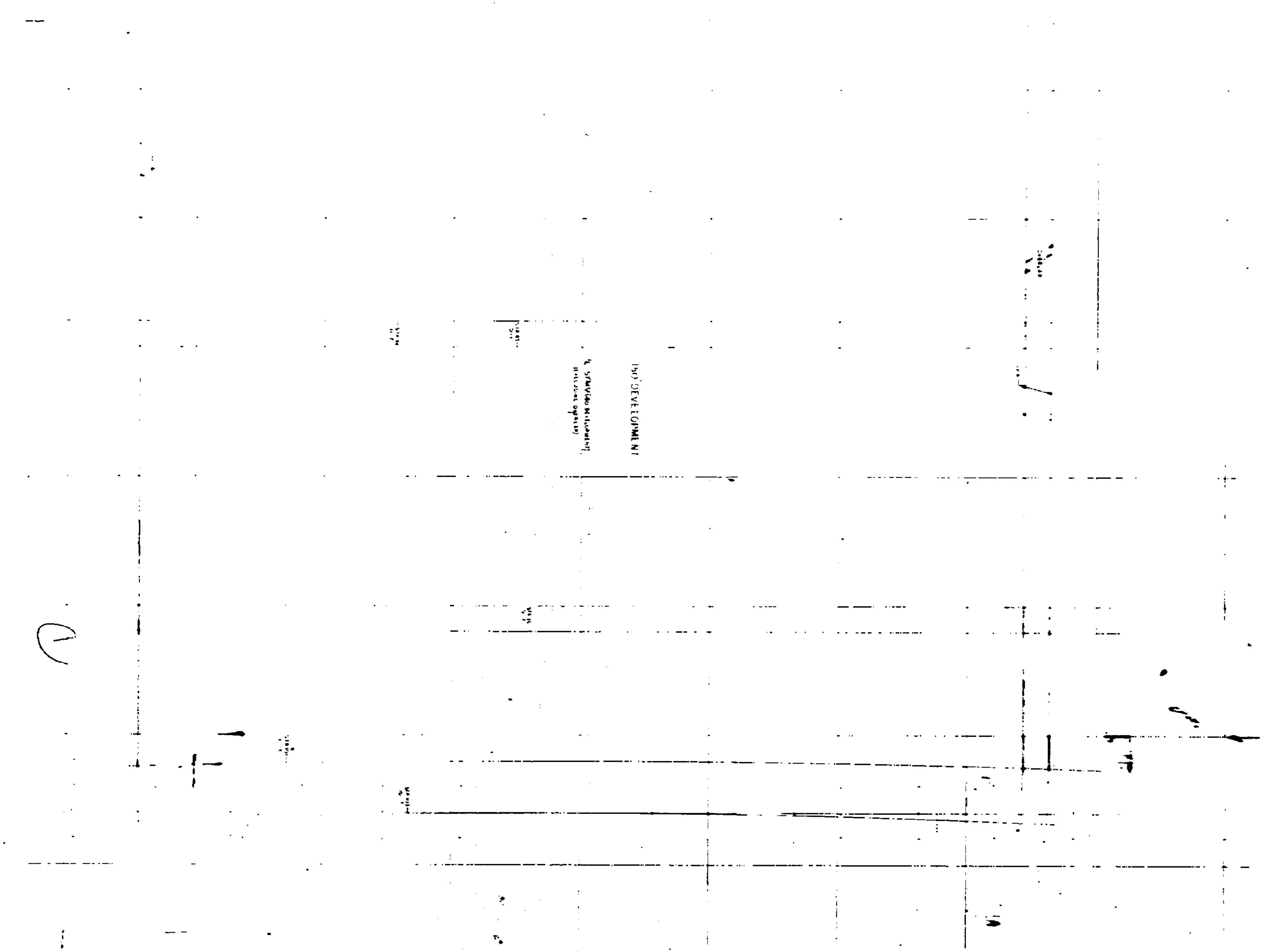
D



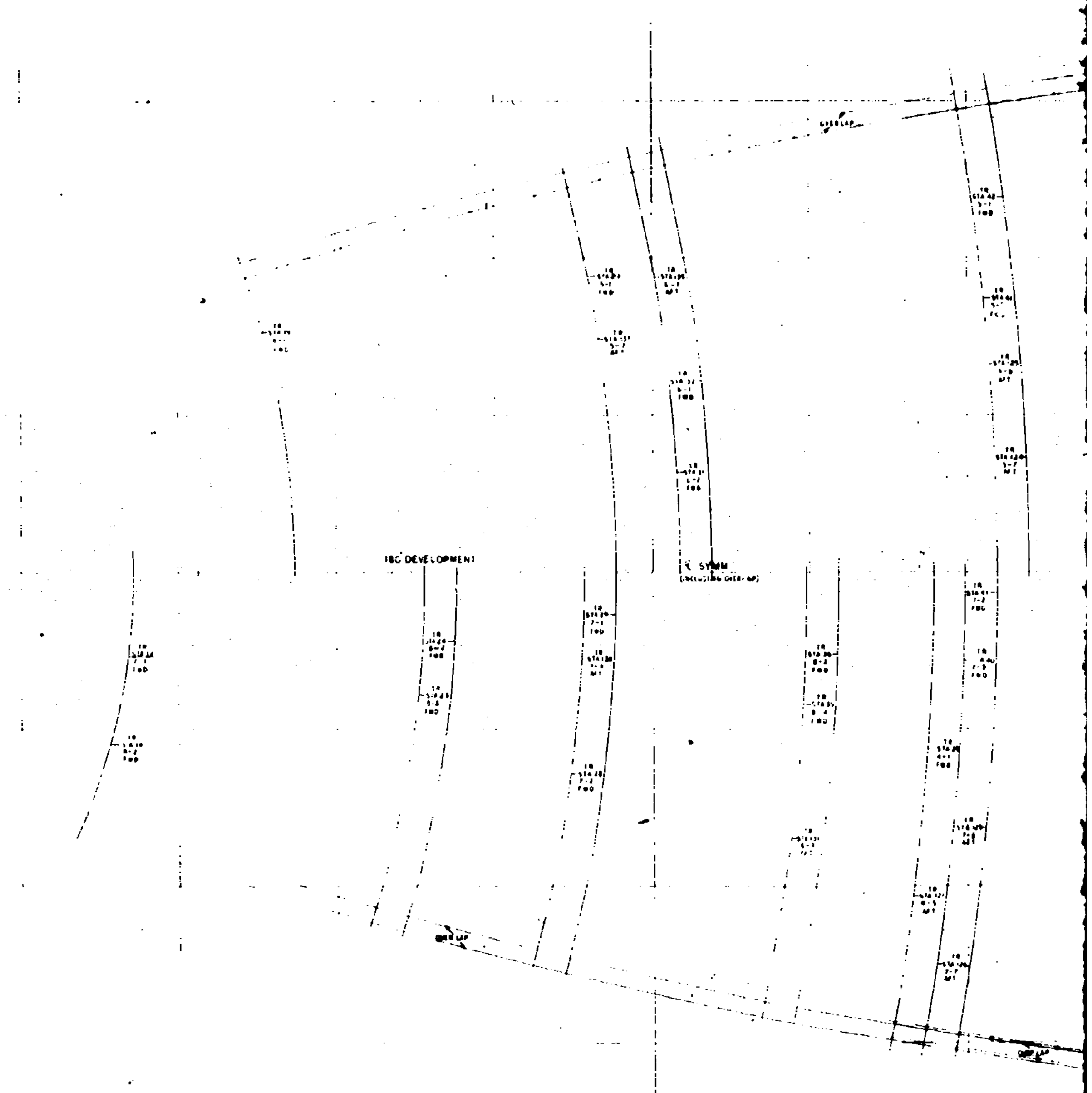


EXPANDABLE RIGIDIZABLE [illegible] TANK
FLAT PATTERN
SHEET [illegible] 4

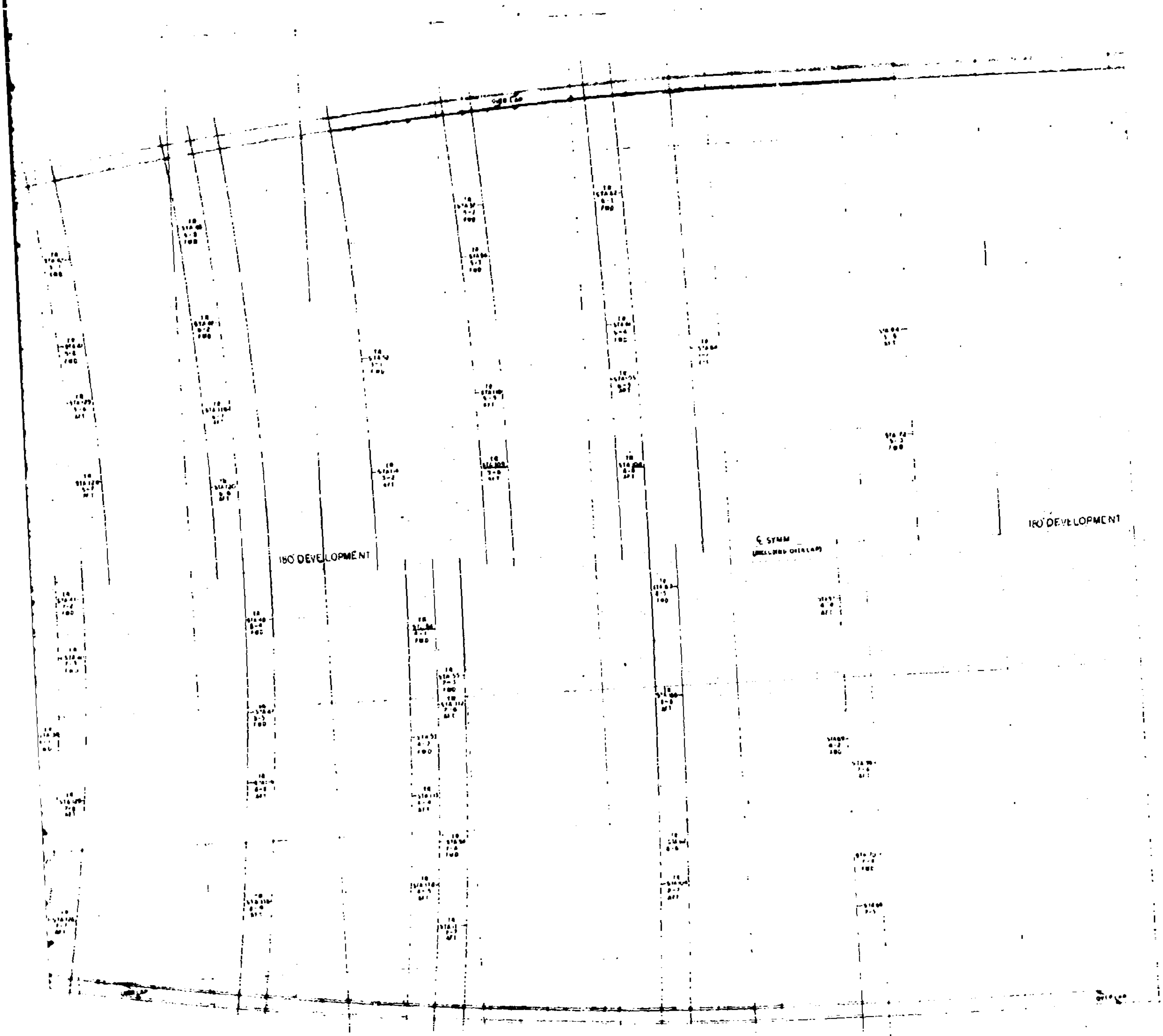
B



"Figure 64 Continued" Flat Patterns of Developed Gores

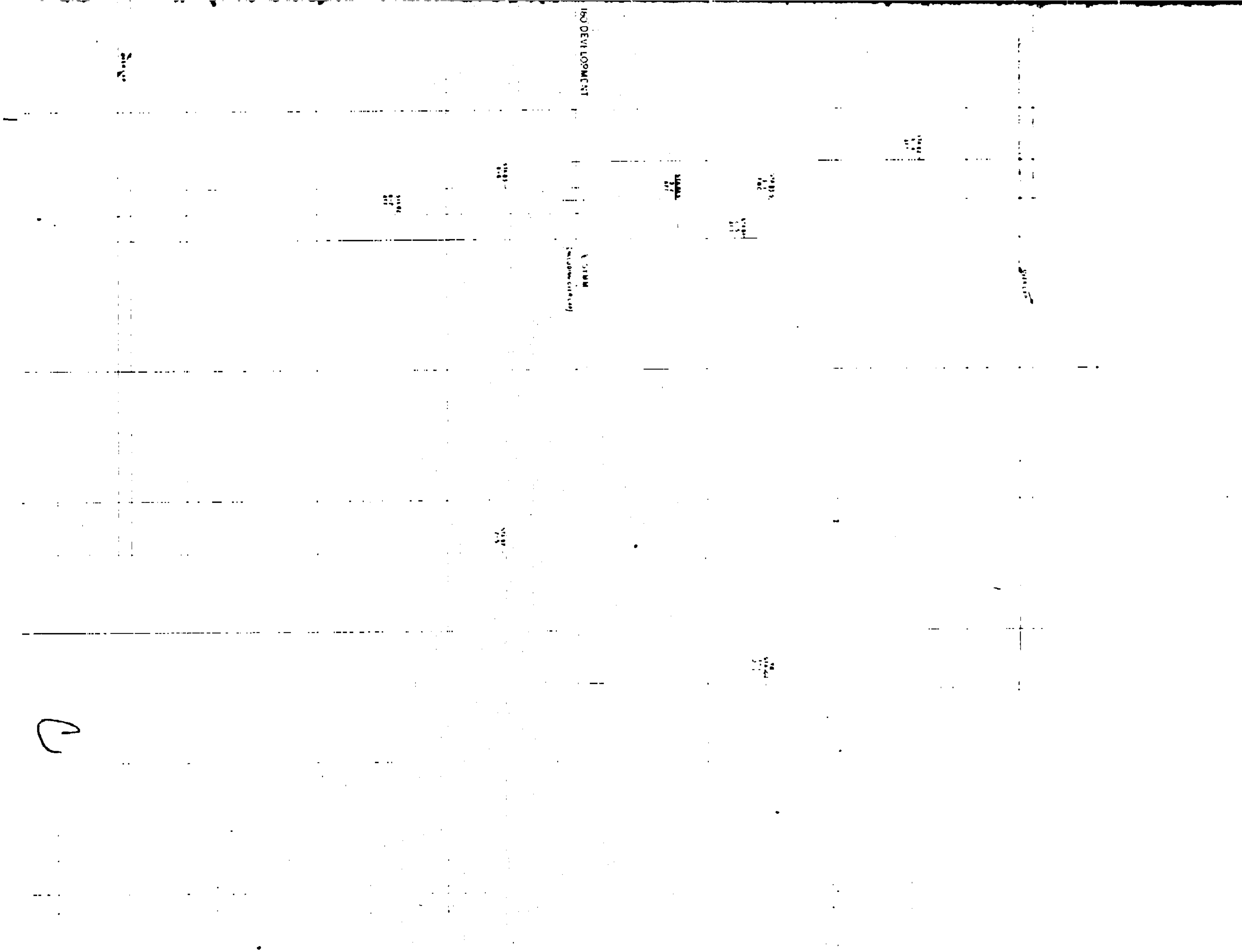


A

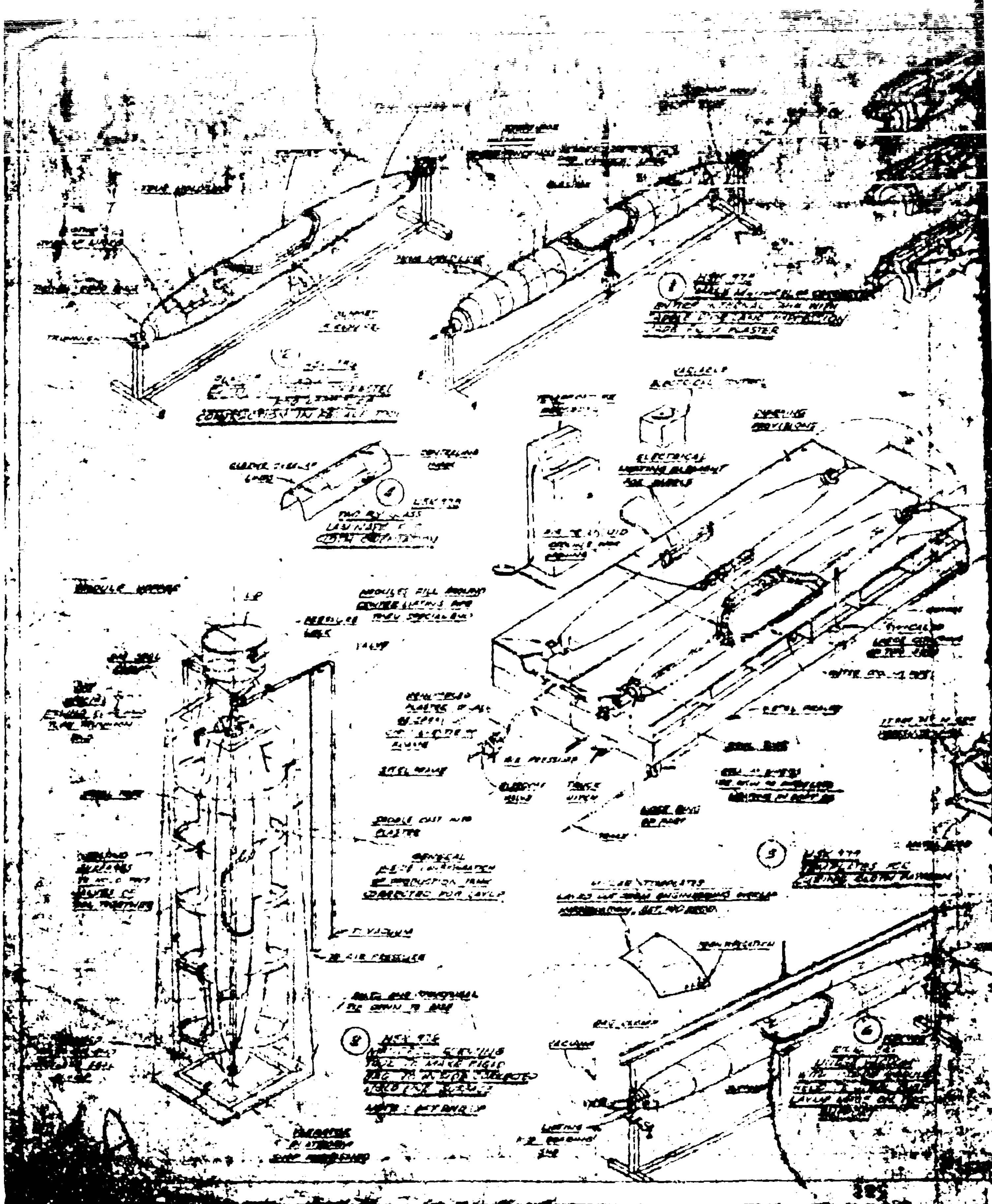


EXPANDABLE RIGIDIZIBLE FUEL TANK
FLAT PATTERNS
SHEET 4 OF 4

B



"Figure 64 Continued" Flat Patterns of Developed Gores


ELECTRICAL
LIGHTING ELEMENT
FOR PANELS
AIR PRESSURE
STEEL FRAME
SADDLE CAST INTO
PLASTER
VACUUM
AIR PRESSURE

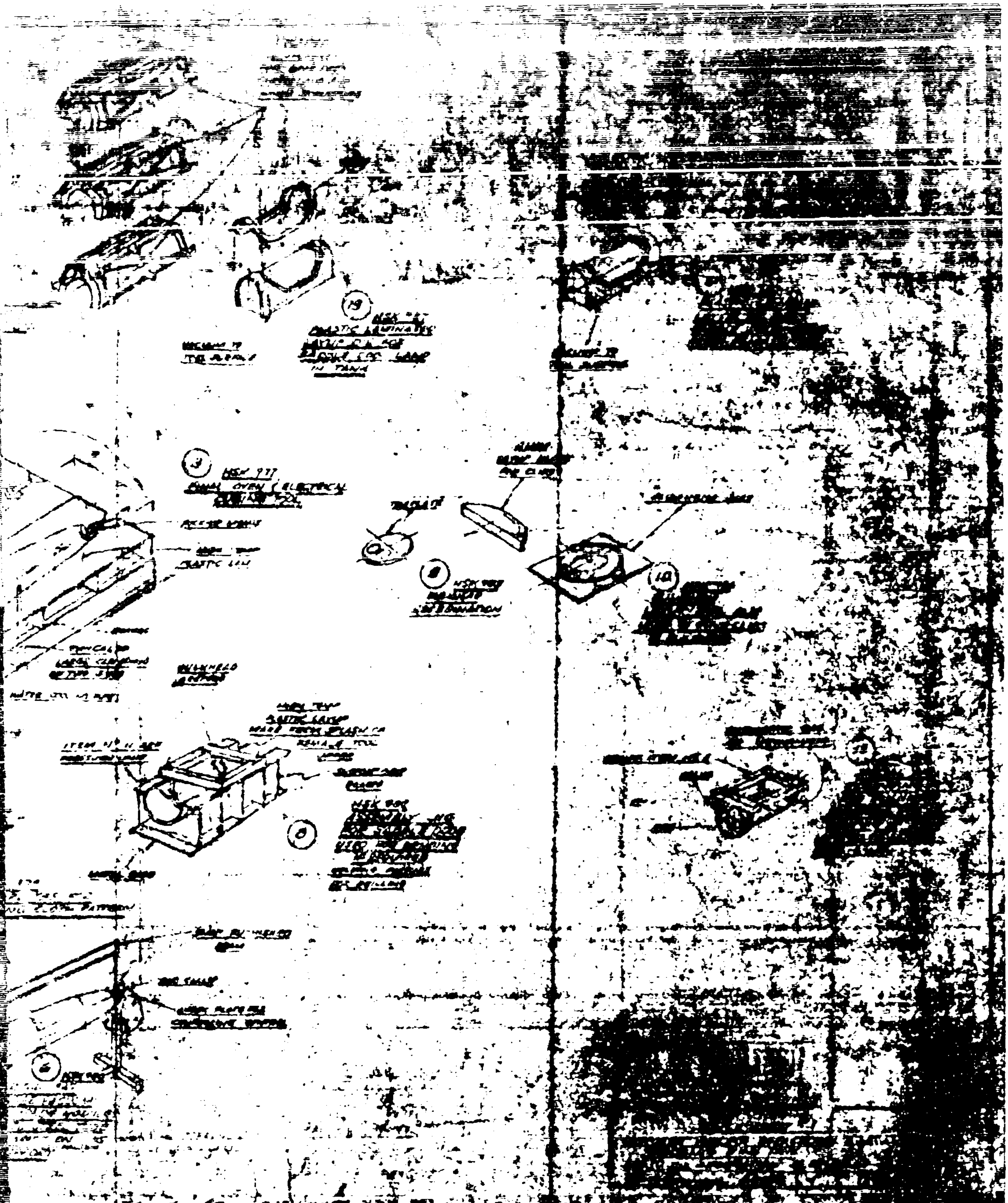
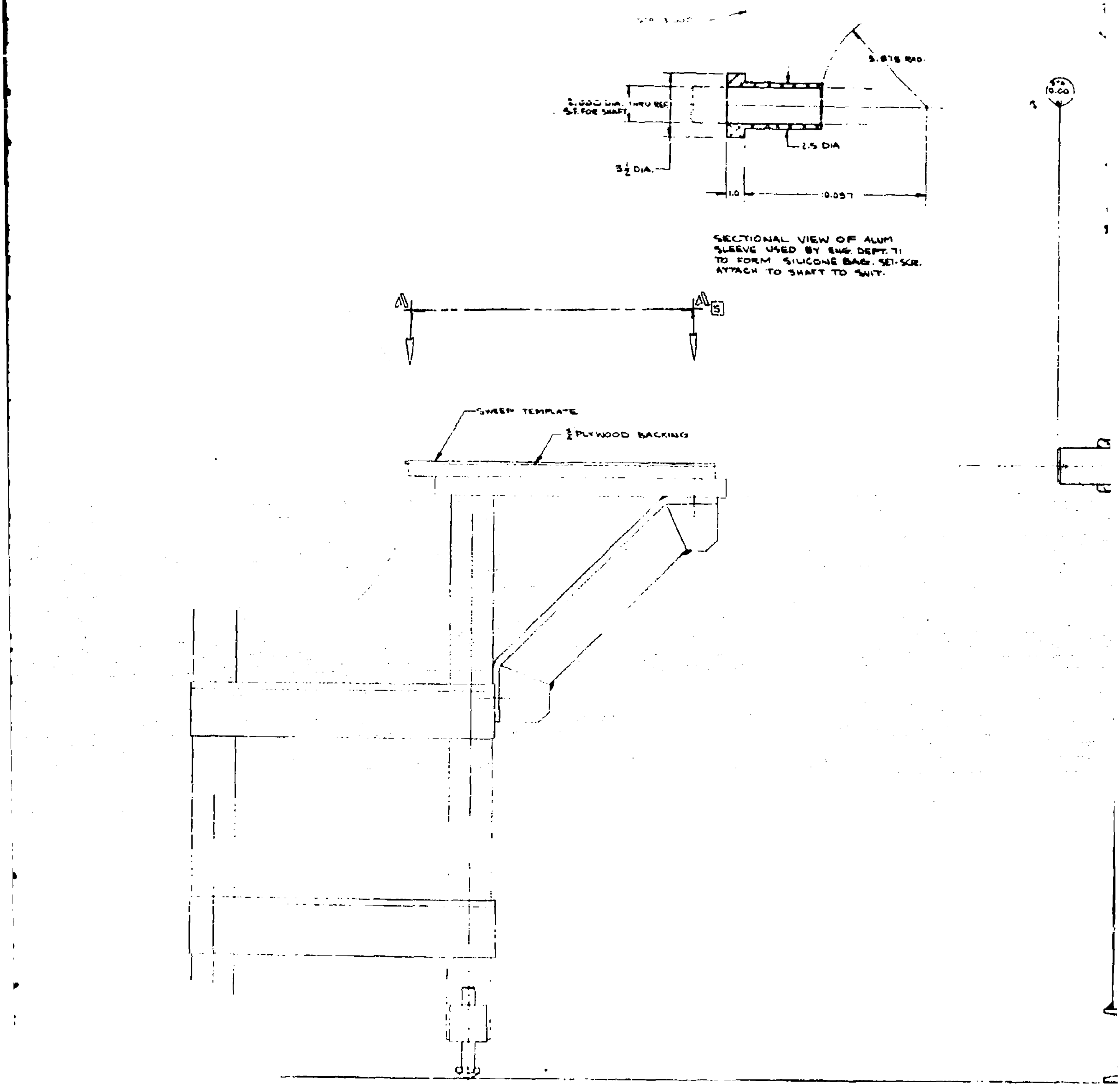
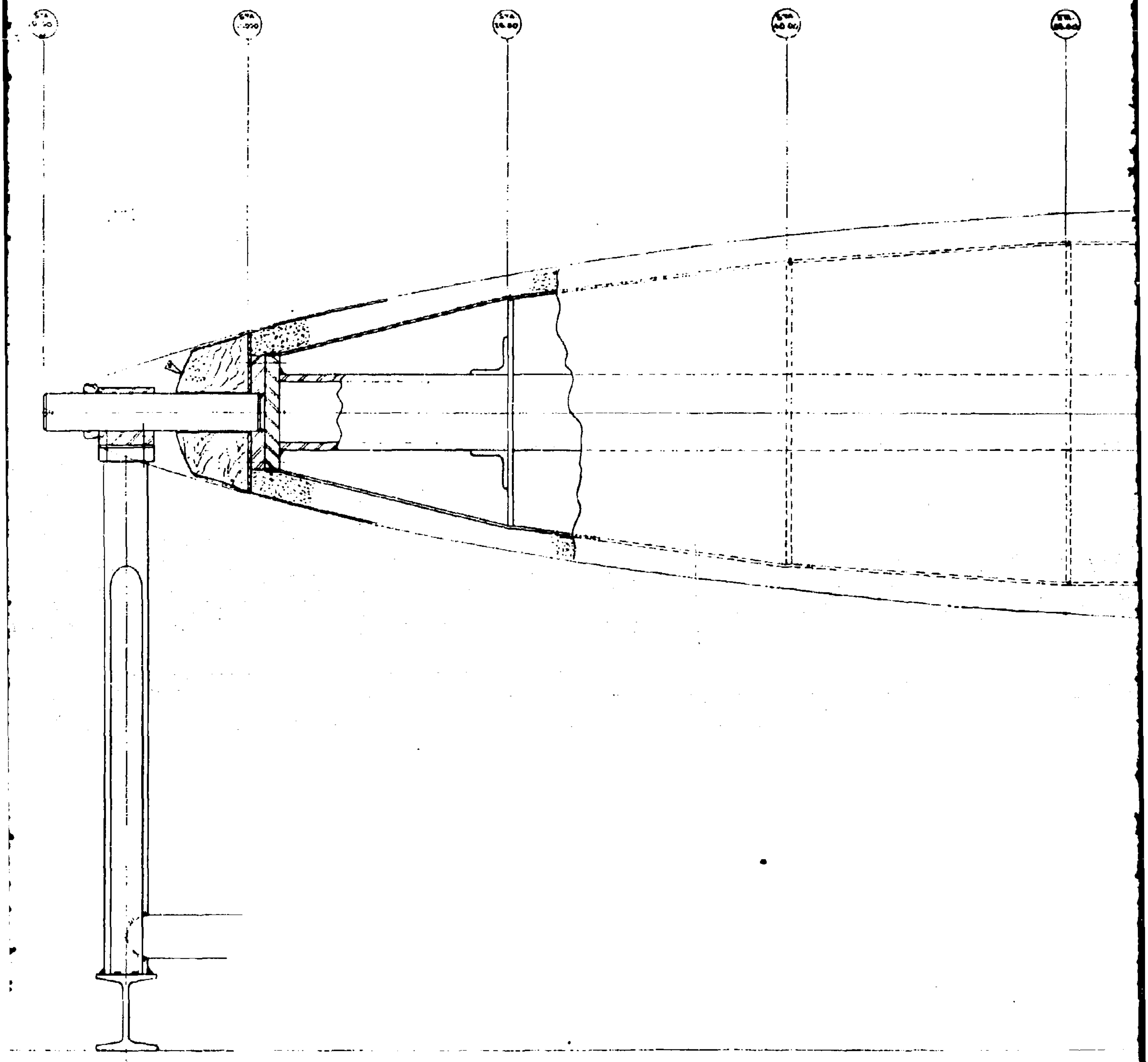


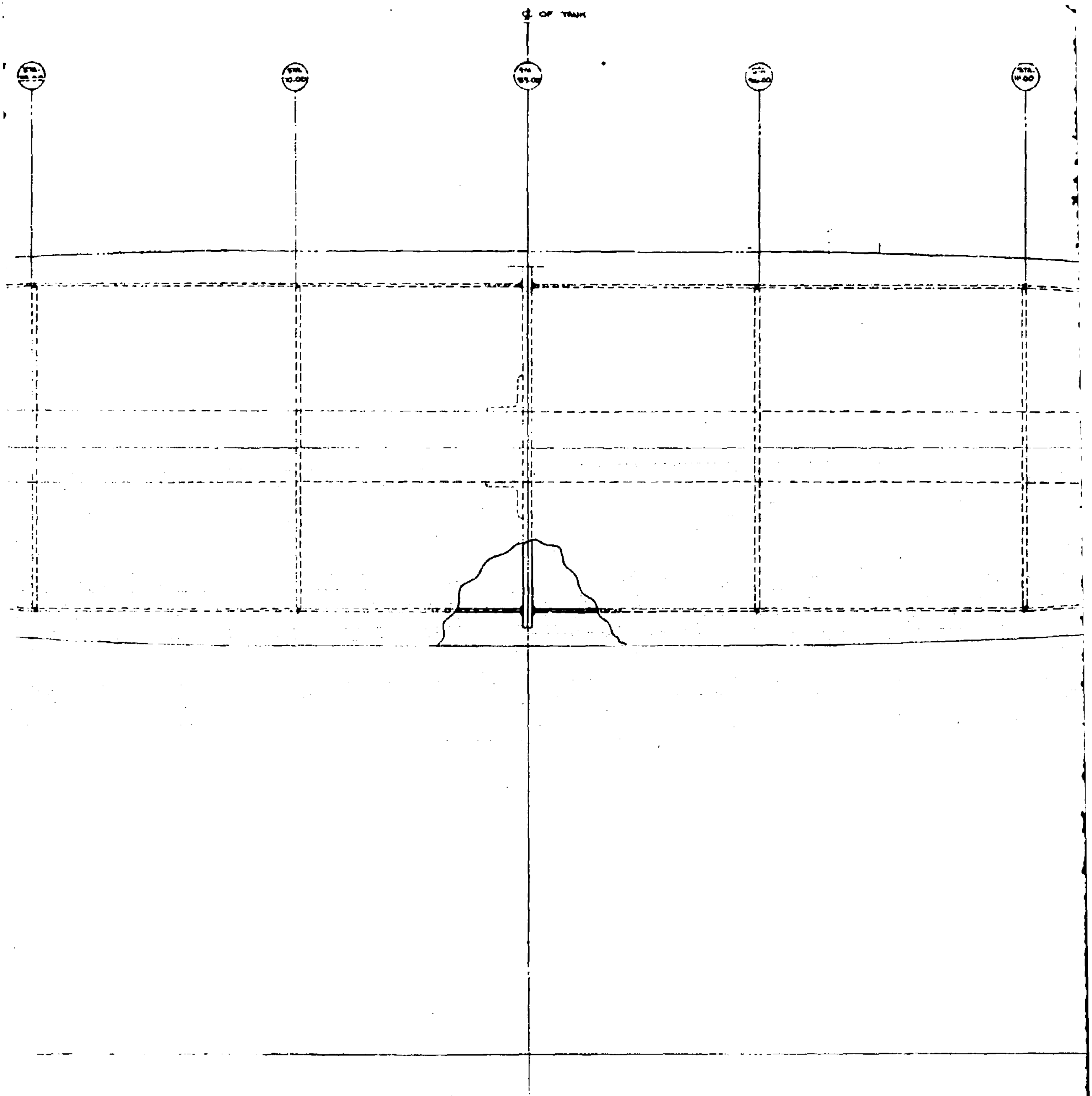
Figure 65 Schematic of Proposed [illegible]



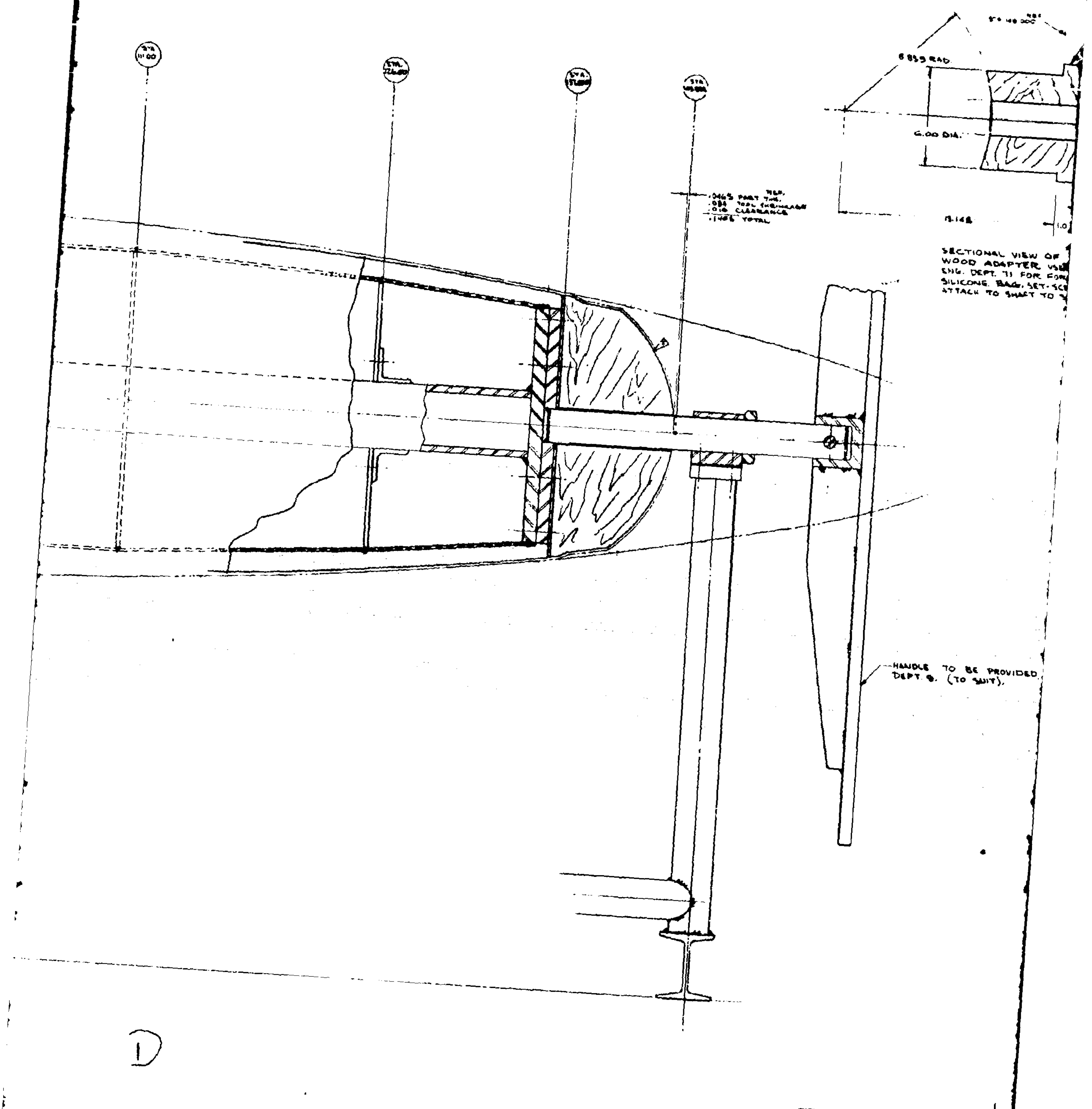
A TEMPLATE APPLICATION

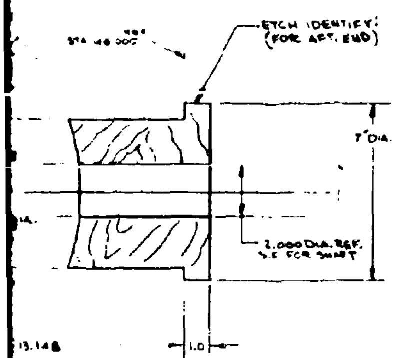


B



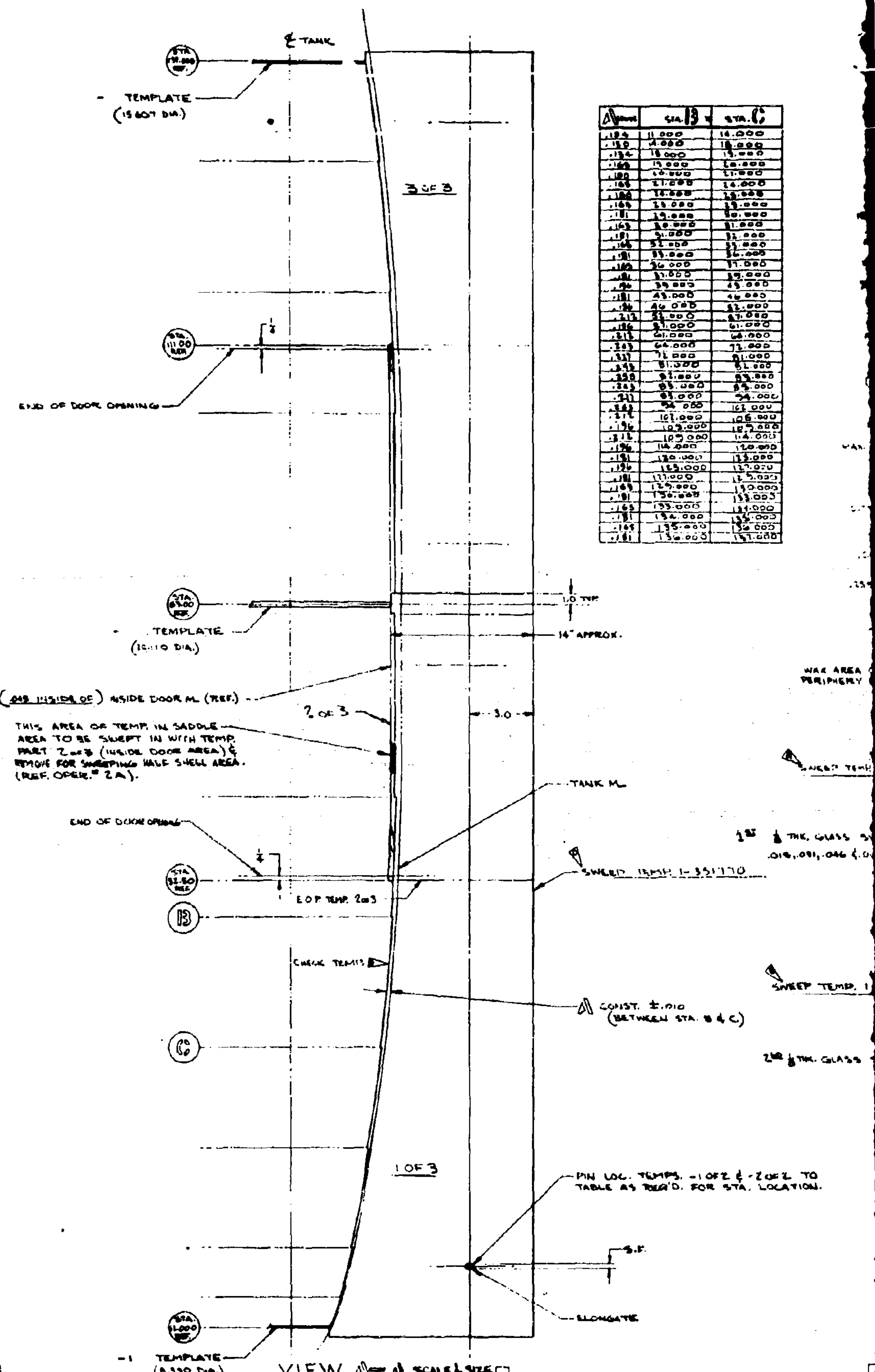
C


STA. 11.00
6.00 DIA.
.0465 PART THK.
.084 TOOL SHRINKAGE
.016 CLEARANCE
.1465 TOTAL
SECTIONAL VIEW OF
WOOD ADAPTER
ENG. DEPT. 71 FOR
SILICONE BAG. SET-
ATTACH TO SHAFT TO
HANDLE TO BE PROVIDED
DEPT. 9. (TO SUIT).



SECTIONAL VIEW OF WOOD ADAPTER USED BY ENG. DEPT. 71 FOR FORMING SILICONE BAG. SET-SCREW ATTACH TO SHAFT TO SUIT.

LE TO BE PROVIDED BY MAKE. T S. (TO SUIT).



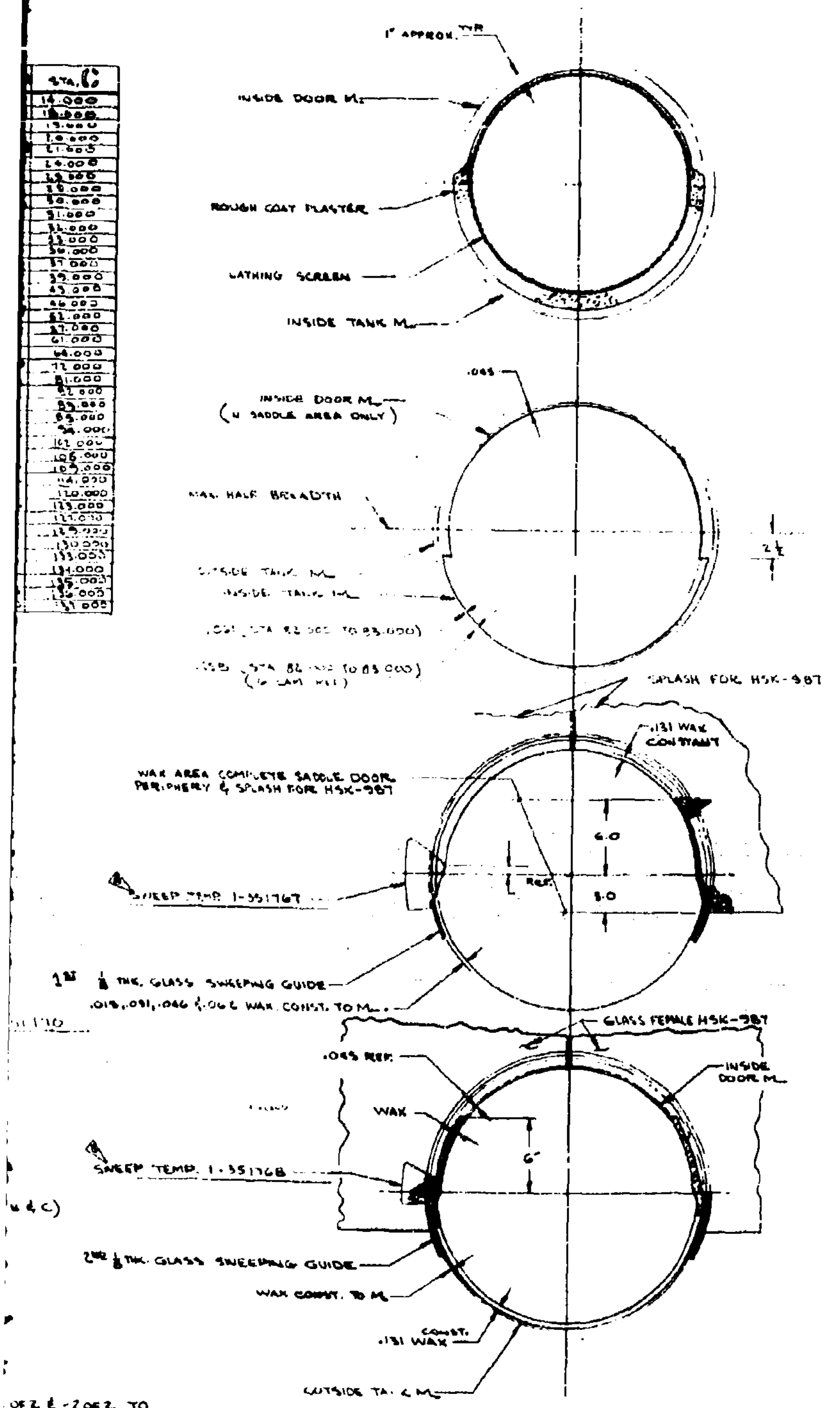
Δ	STA. B	STA. C
.184	11.000	14.000
.150	14.000	18.000
.134	15.000	19.000
.169	19.000	20.000
.180	20.000	21.000
.165	21.000	24.000
.180	24.000	25.000
.169	25.000	29.000
.181	29.000	30.000
.163	30.000	31.000
.181	31.000	32.000
.166	32.000	33.000
.181	33.000	36.000
.180	36.000	37.000
.181	37.000	39.000
.196	39.000	43.000
.181	43.000	46.000
.196	46.000	52.000
.212	52.000	57.000
.196	57.000	61.000
.212	61.000	64.000
.243	64.000	72.000
.227	72.000	81.000
.243	81.000	82.000
.258	82.000	83.000
.243	85.000	89.000
.227	89.000	94.000
.243	94.000	102.000
.212	102.000	106.000
.196	103.000	107.000
.212	105.000	114.000
.196	114.000	120.000
.181	120.000	123.000
.196	123.000	127.000
.181	127.000	125.000
.169	129.000	130.000
.181	130.000	133.000
.165	133.000	134.000
.181	134.000	135.000
.165	135.000	136.000
.181	136.000	137.000

VIEW A—A SCALE ½ SIZE

E

6

5



OPER. #1

(A) ROUGH COAT PLASTER TO WITHIN APPROX. 1" INSIDE TANK & DOOR M. IN ENTIRE TOOL.
(B) FINISH PLASTER COAT EXCEPT FROM STA. 82.50 TO STA. 111.00 SADDLE DOOR AREA.

OPER. #2

(A) FINISH PLASTER HALF SHELL AREA WITHIN $2\frac{1}{2}$ (OPPOSITE SADDLE DOOR SIDE) TO MAX. HALF BREADTH, & .045 IN FROM INSIDE DOOR M. IN SADDLE DOOR AREA.

OPER. #3

(A) SWEEP IN TAPER AREA AROUND SADDLE DOOR, USING GLASS SWEEPING GUIDE #1 & SWEEP TEMP. 1-351767. NOTE WAX TO M. UNDER GLASS GUIDE.

OPER. #4

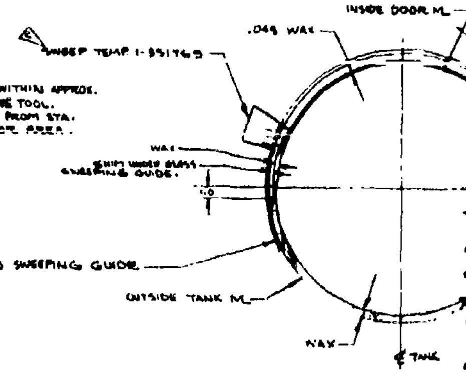
(A) CONSTRUCT TOWER TOOL HSK-976.

OPER. #5

(A) WAX UP PLASTER (REF. .131) TO INSIDE OF LAND.
(B) POUR SPLASH FOR MALE HALF OF HSK-987. (INSIDE M. OF LAND)

OPER. #6

(A) LAY-OUT & CUT-OUT 2ND GUIDE (REF TAPER ON LAND AT MAX. HALF BREADTH & CONSTANT AROUND DOOR PERIPHERY.
(B) WAX & SWEEP PLASTER TO OUTSIDE LAND M. NOTE CONST. WAX TO M. UNDER GLASS SWEEPING GUIDE #2 WITH SWEEP TEMP. 1-351768.
(C) GLASS LAY UP FOR FEMALE HALF OF HSK-987 (OUTSIDE M. OF LAND)



OPER. #7

(A) LAY-OUT & CUT-OUT 3RD G... INSIDE DOOR M. & ... DI...
(B) REMOVE PLASTER IN AR... SWEEPING (REF OPER. #6)
(C) WAX .045 SADDLE DOOR... DOOR M. & WAX TO OUTS... OPPOSITE SIDE & AS...
(D) SPLINE IN PLASTER US... GUIDE #3 & SWEEP TEMP. ...
(E) POUR SPLASH FOR LA... INSIDE DOOR TOOL HS...

...OF 2 & -2 OF 2 TO ...DR STA. LOCATION.

SEQUENCE OF OPERATIONS FOR SADDLE DOOR AREA (SHOWN AT STA. 82.00 SCALE ¼ SIZE APPROX.)
(VIEW LOOKING AFT)

1-372017 J.T.
1-369096 J.T.
1-369095 J.T.
1-351770 J.T.
1-351769 J.T.
1-351768 J.T.
1-351767 J.T.
C/D INFO.

4 3 2

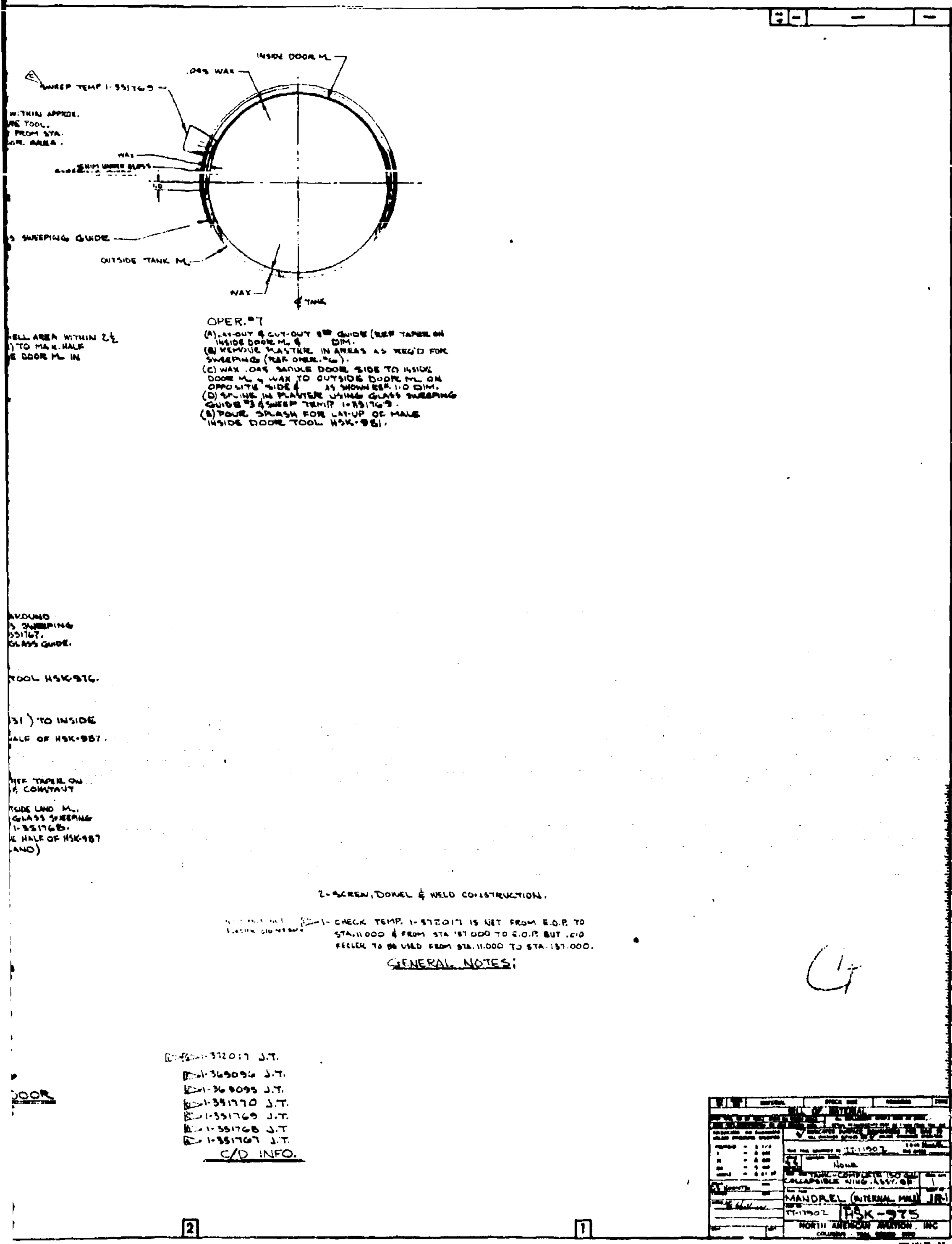
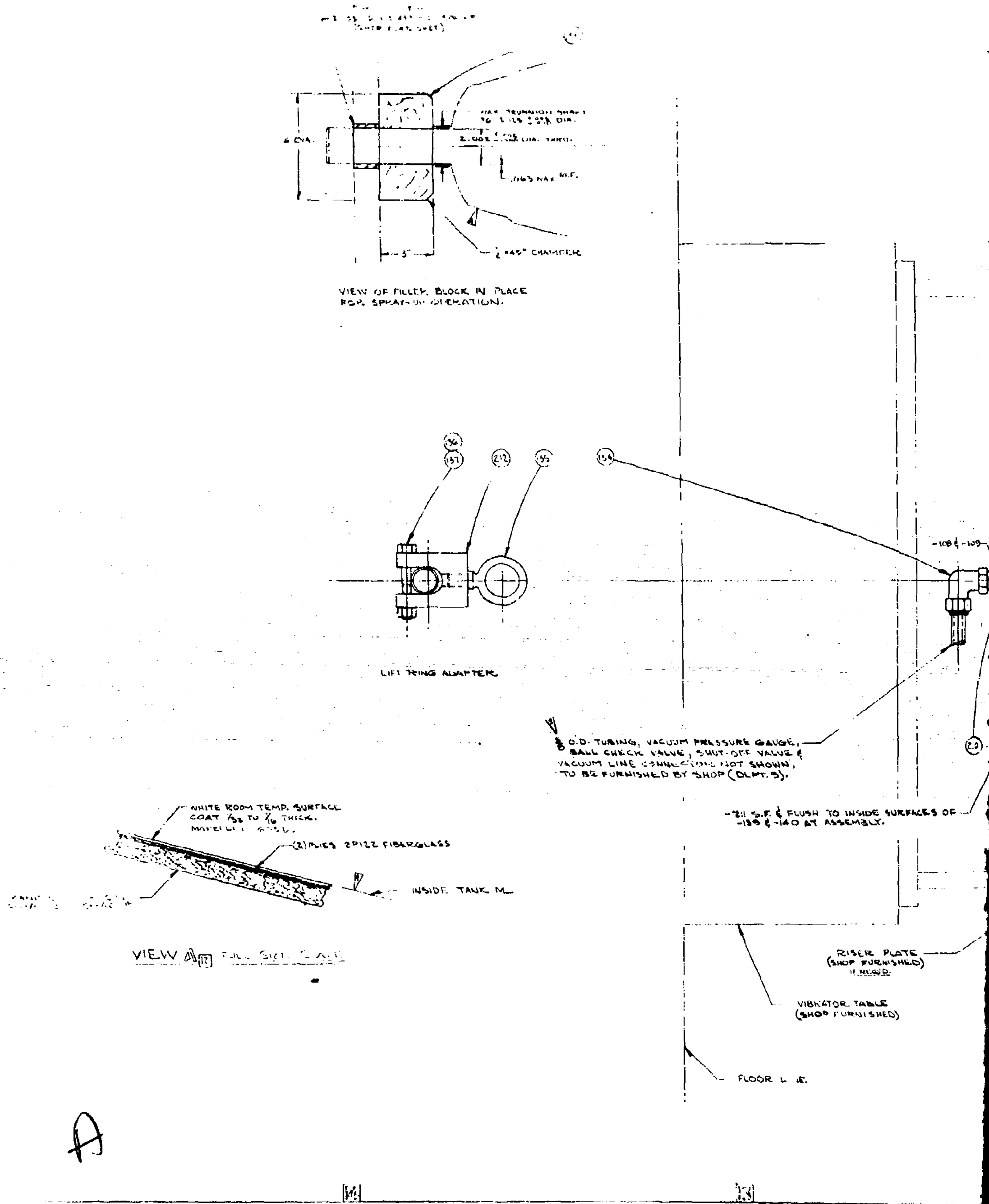
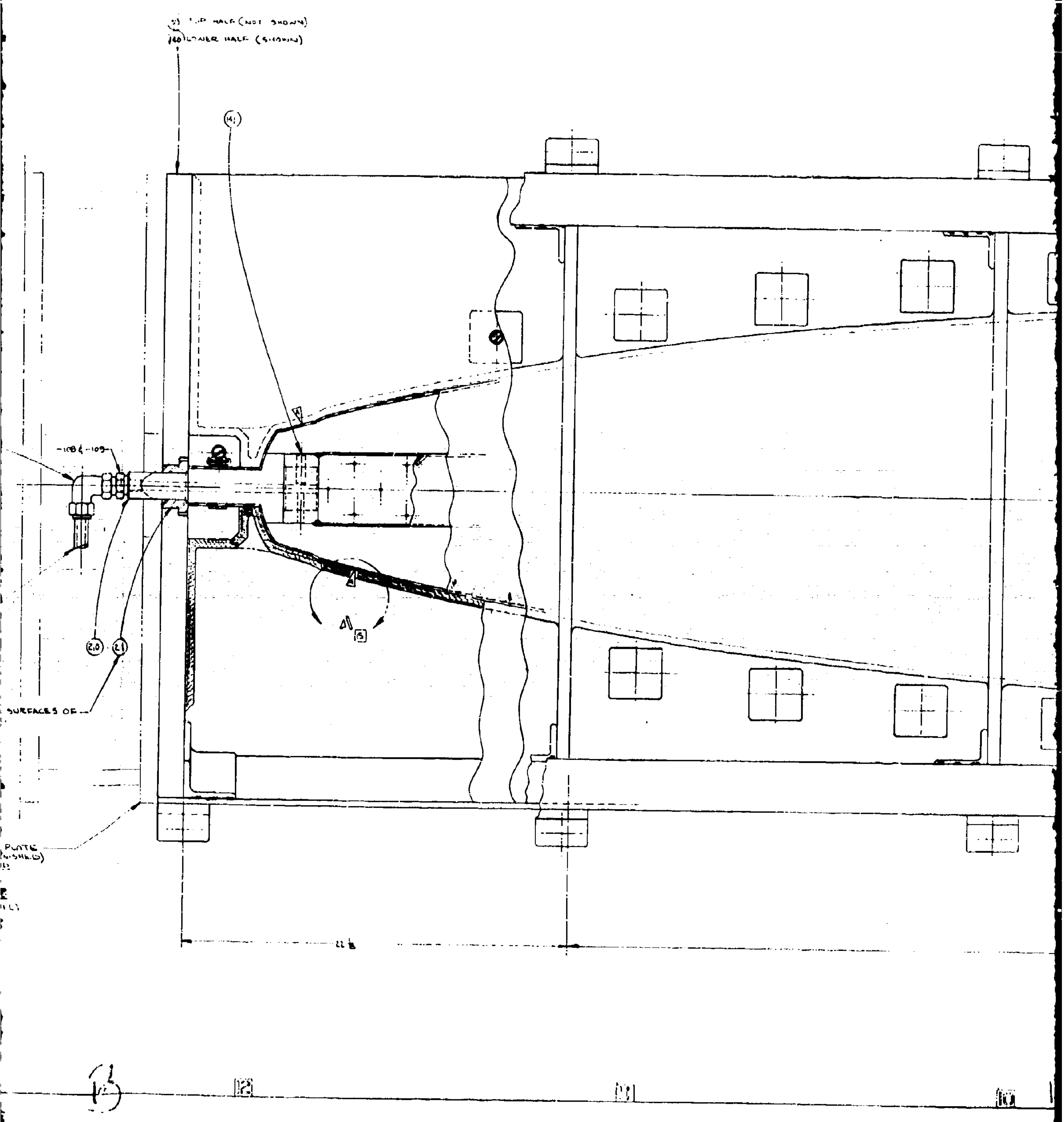


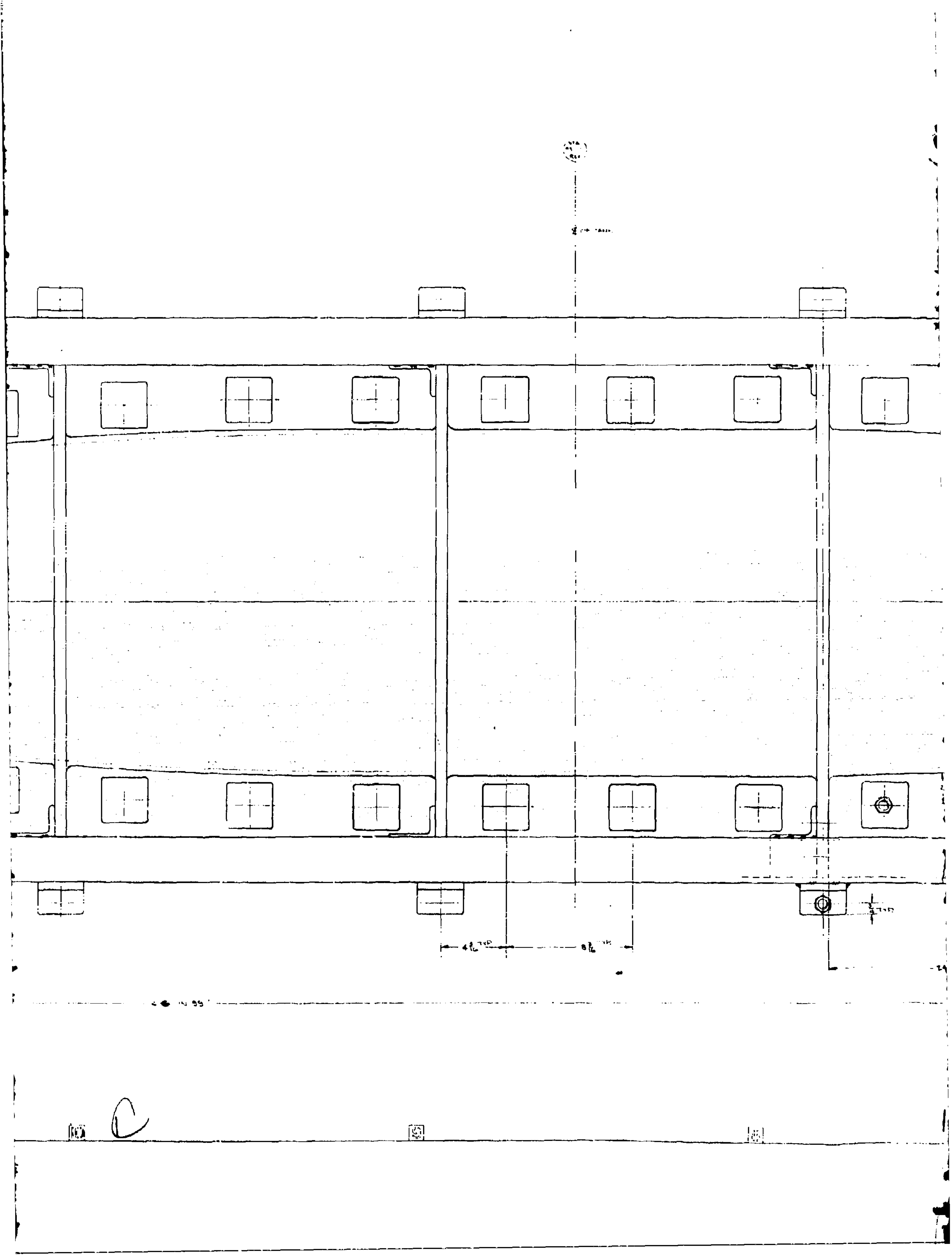
Figure 66 Internal Male Plaster Mandrel

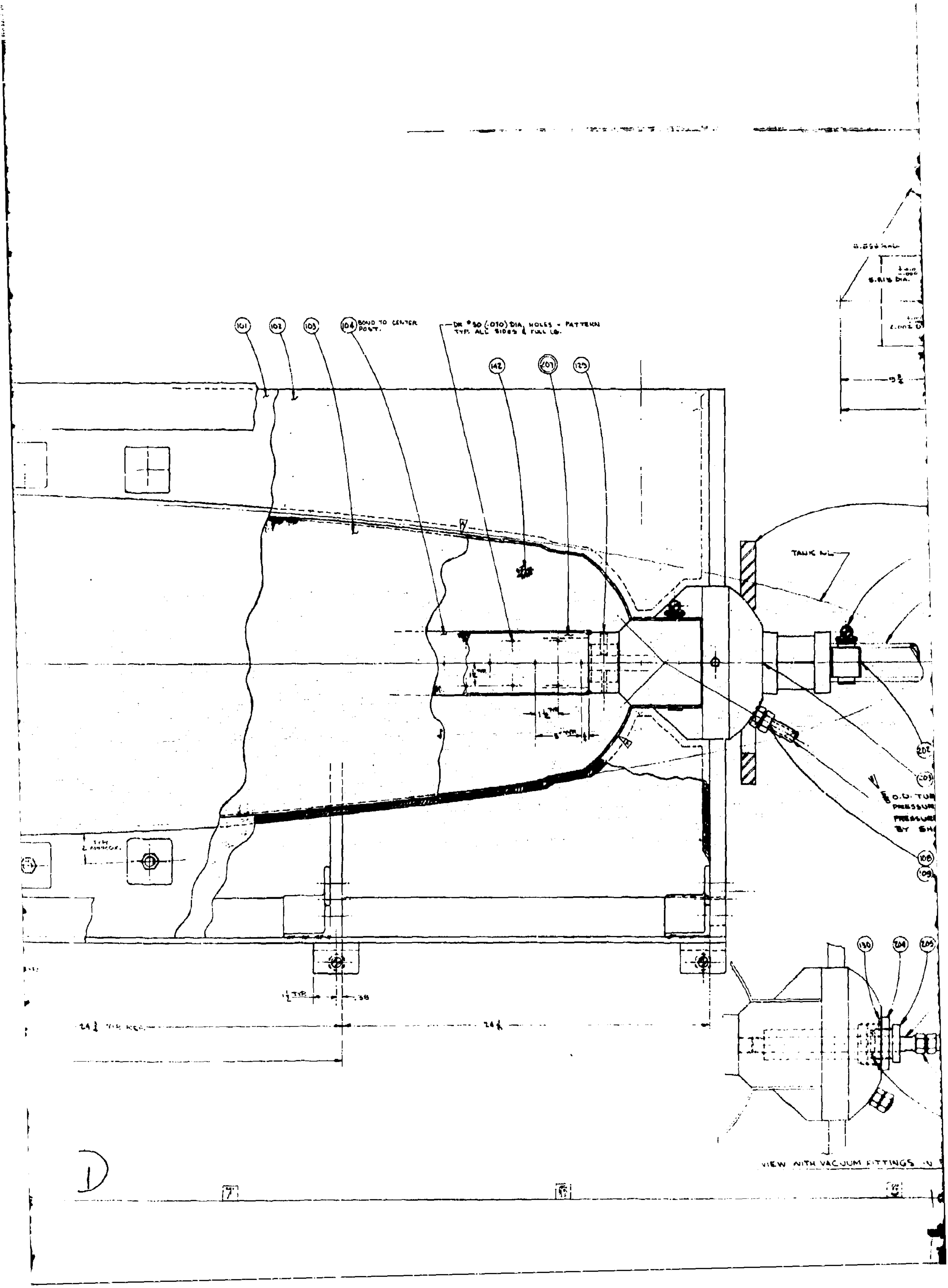


VIEW OF FILLER BLOCK IN PLACE FOR SPRAY-UP OPERATION.
6 DIA.
.063 MAX R.F.
1/8 x 45° CHAMFER
LIFT RING ADAPTER
136
137
212
135
134
-108 & -109
3/8 O.D. TUBING, VACUUM PRESSURE GAUGE, BALL CHECK VALVE, SHUT-OFF VALVE & VACUUM LINE CONNECTIONS NOT SHOWN, TO BE FURNISHED BY SHOP (DEPT. 9).
-211 S.F. & FLUSH TO INSIDE SURFACES OF -139 & -140 AT ASSEMBLY.
WHITE ROOM TEMP. SURFACE COAT 1/32 TO 1/16 THICK.
(2) PLIES 2P122 FIBERGLASS
INSIDE TANK ML
VIEW
RISER PLATE (SHOP FURNISHED)
VIBRATOR TABLE (SHOP FURNISHED)
FLOOR LINE
A
14
13

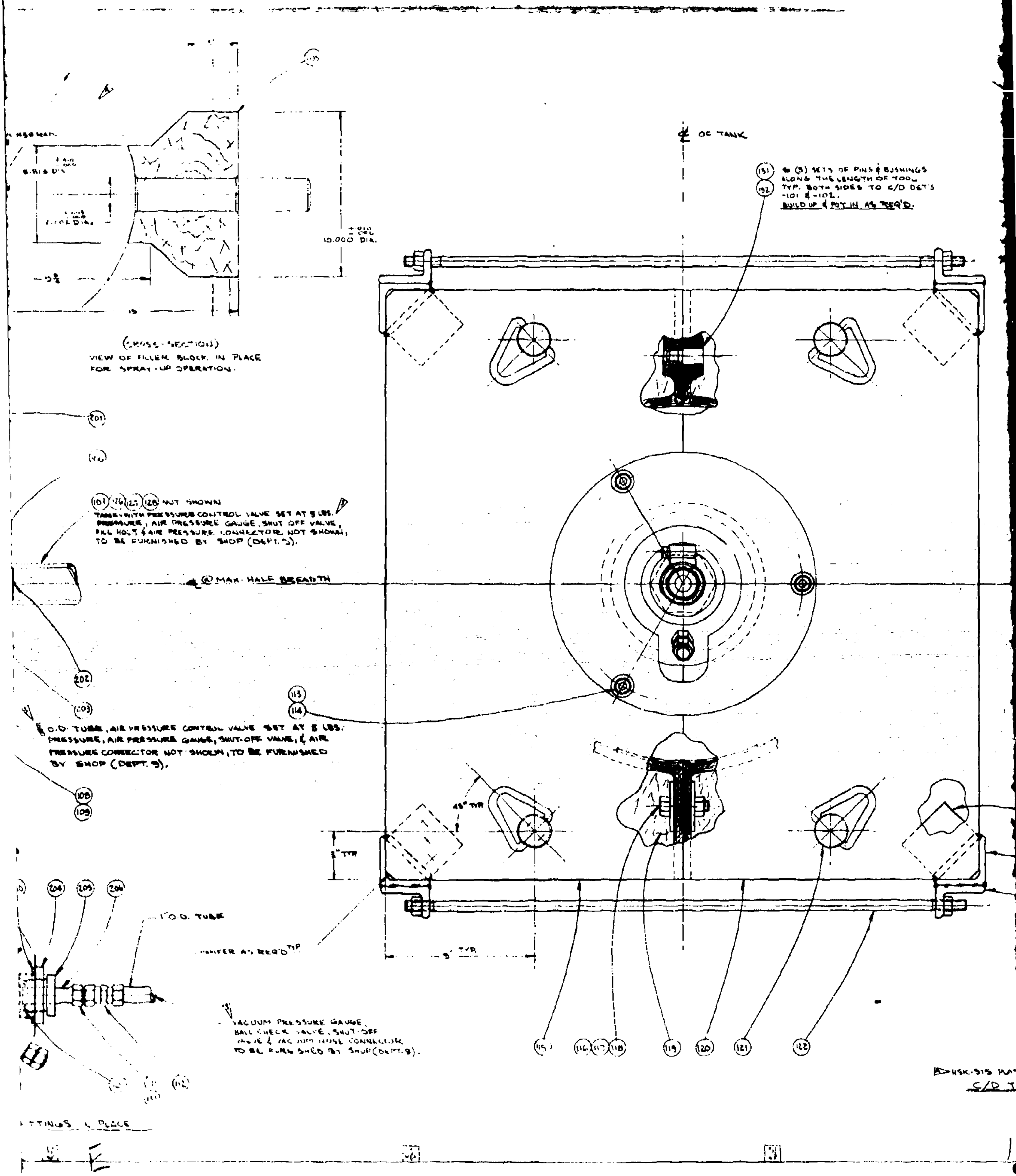


108 & 109
41
20
21
SURFACES OF
PLATE
12
11
10





101
102
103
104 BOND TO CENTER POST.
DR #50 (.070) DIA. HOLES - PATTERN TYP. ALL SIDES & FULL LG.
142
207
125
TANK
202
203
108
109
130
204
205
24 1/4
VIEW WITH VACUUM FITTINGS
D
7
6



(CROSS-SECTION)
VIEW OF FILLER BLOCK IN PLACE
FOR SPRAY-UP OPERATION.
10.000 DIA.
℄ OF TANK
(131) (132) (3) SETS OF PINS & BUSHINGS ALONG THE LENGTH OF TOOL TYP. BOTH SIDES TO C/D DET'S -101 & -102.
BUILD UP & POT IN AS REQ'D.
(201)
(107) (126) (127) (128) NOT SHOWN
TANK WITH PRESSURE CONTROL VALVE SET AT 5 LBS. PRESSURE, AIR PRESSURE GAUGE, SHUT OFF VALVE, FILL HOLE & AIR PRESSURE CONNECTOR NOT SHOWN, TO BE FURNISHED BY SHOP (DEPT. 9).
@ MAX. HALF BREADTH
(202)
(113) (114)
O.D. TUBE, AIR PRESSURE CONTROL VALVE SET AT 5 LBS. PRESSURE, AIR PRESSURE GAUGE, SHUT-OFF VALVE, & AIR PRESSURE CONNECTOR NOT SHOWN, TO BE FURNISHED BY SHOP (DEPT. 9).
(108) (109)
45° TYP.
3" TYP.
(204) (205) (206)
1" O.D. TUBE
CHAMFER AS REQ'D TYP.
9" TYP.
VACUUM PRESSURE GAUGE, BALL CHECK VALVE, SHUT-OFF VALVE & VACUUM HOSE CONNECTOR TO BE FURNISHED BY SHOP (DEPT. 9).
(115) (116) (117) (118) (119) (120) (121) (122)
FITTINGS IN PLACE

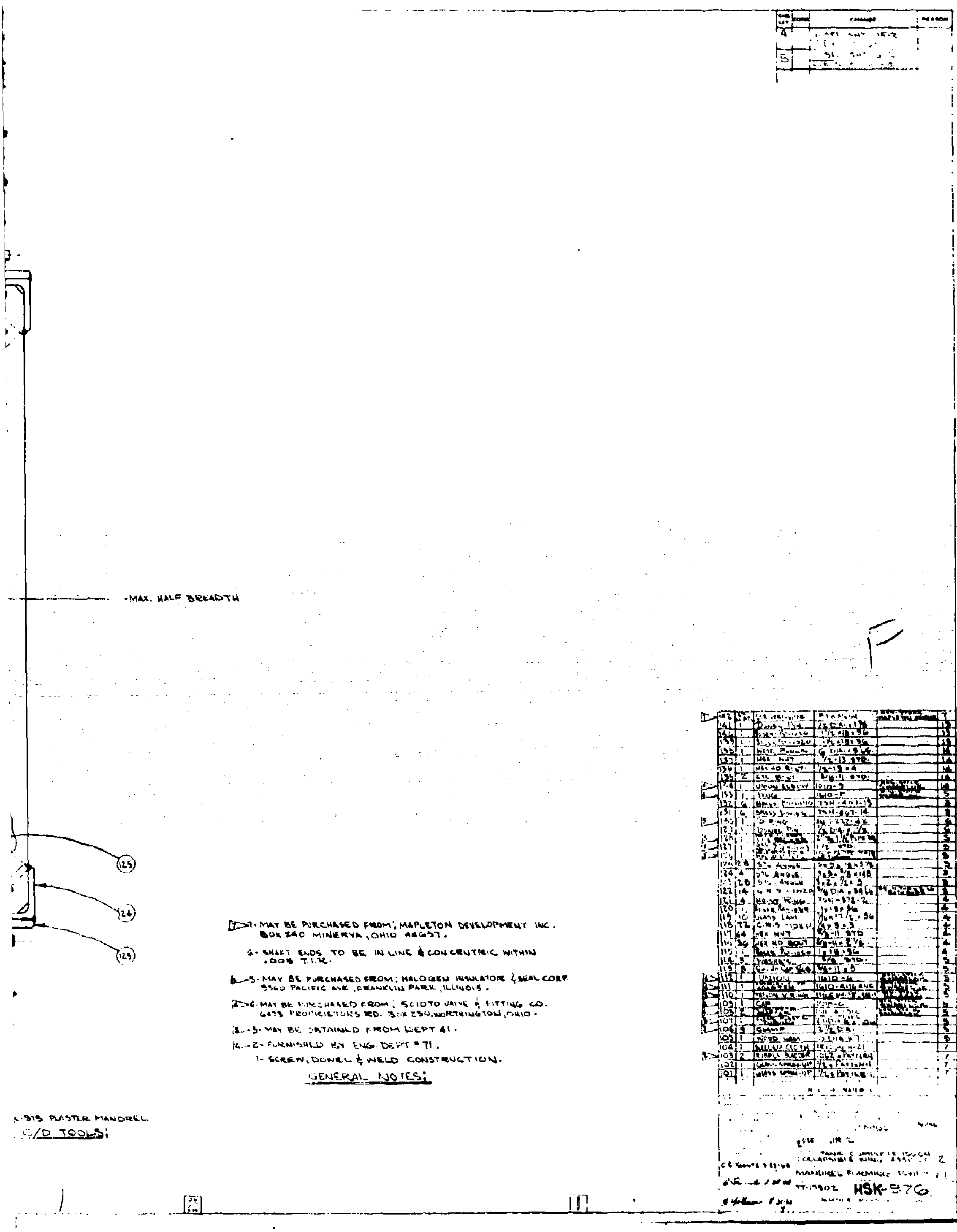
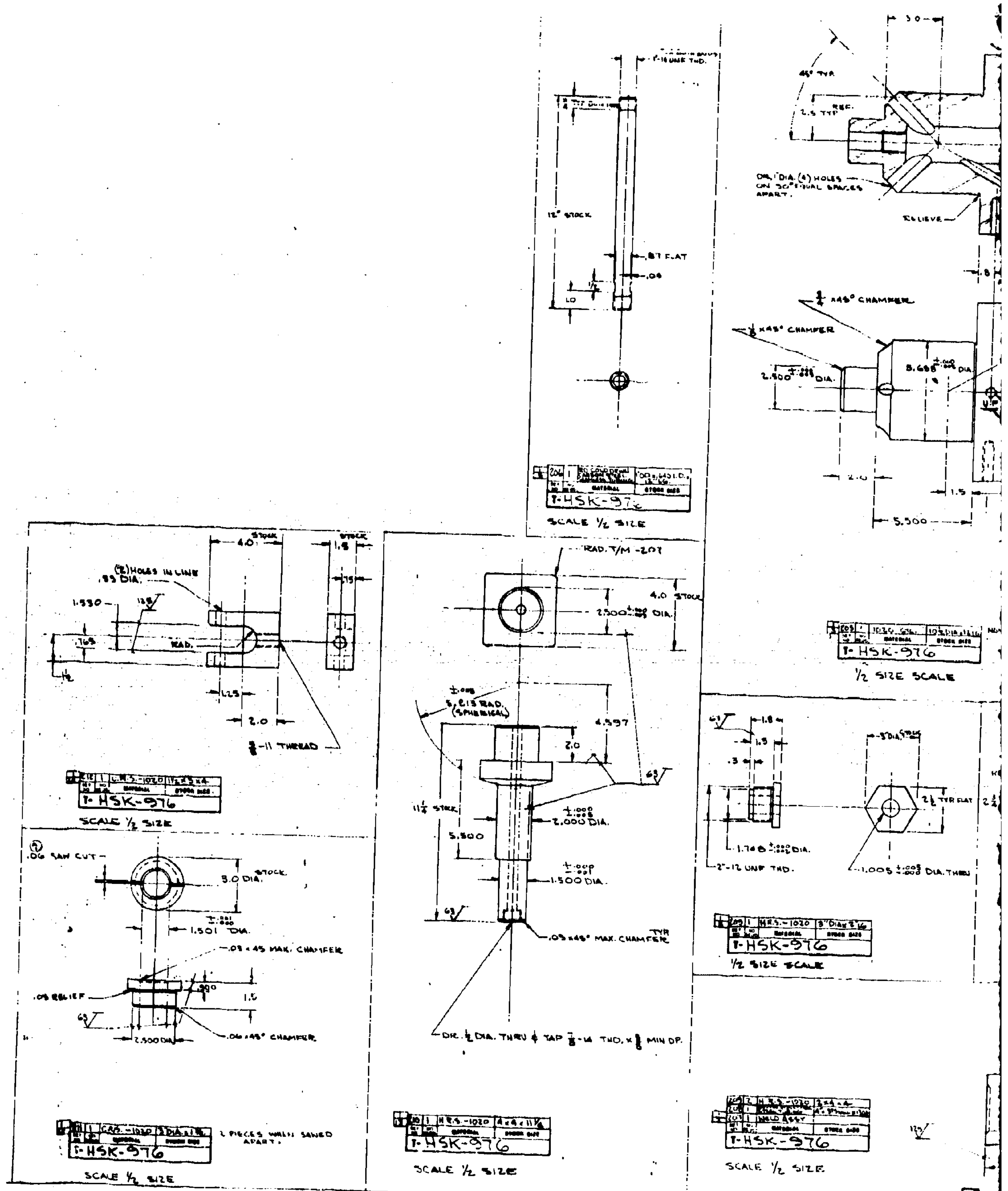
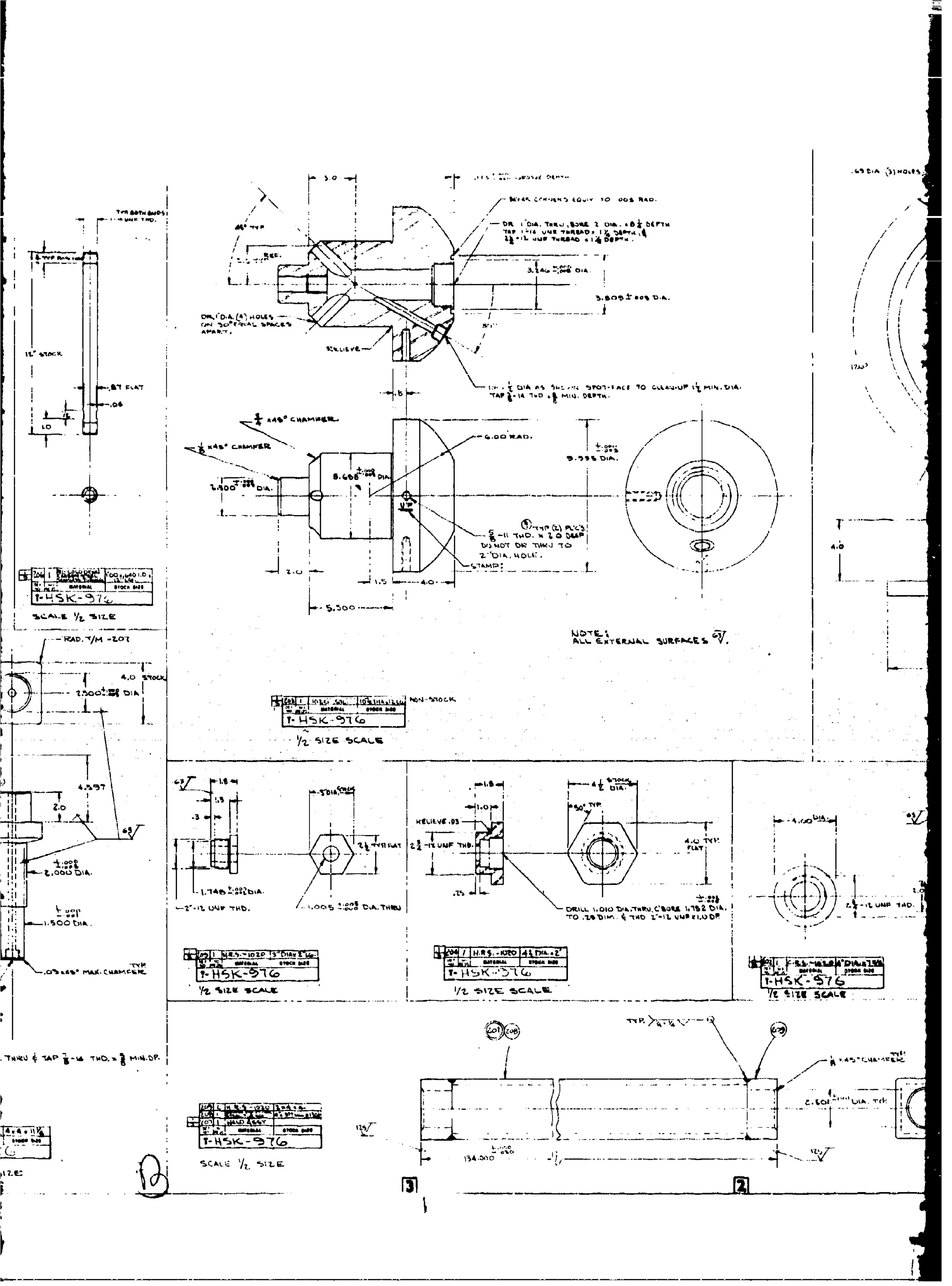


Figure 67 Male Mandrel Forming Tower

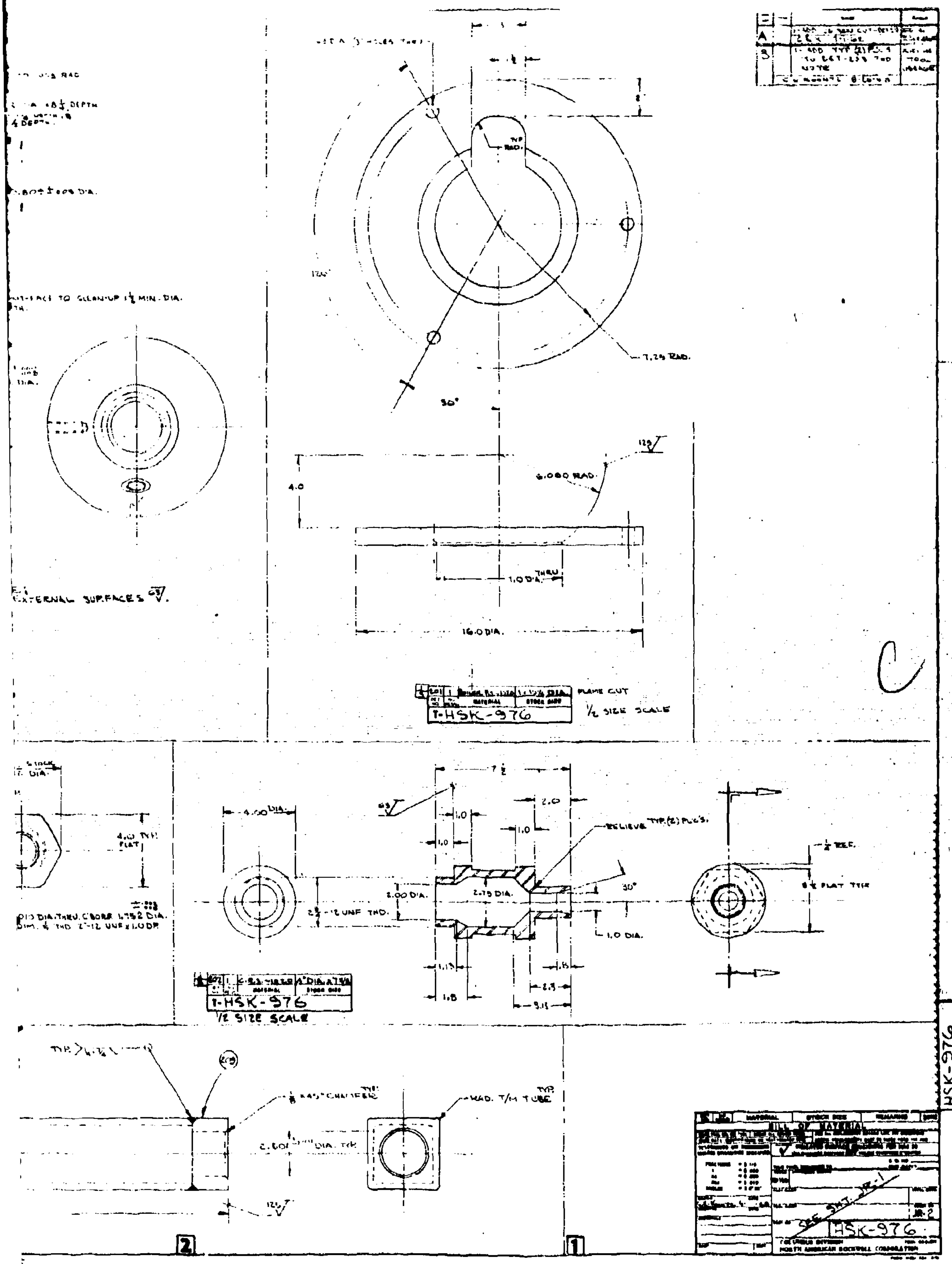


1-16 UNF THD.
12" STOCK
.87 FLAT
.04
1.0
206 | 1 | SO. COLD DRAWN CARBON STEEL | 1.00 x .6401.D. 12"LG.
1-HSK-976
SCALE 1/2 SIZE
45° TYP.
2.5 TYP. REF.
DR. 1" DIA. (4) HOLES ON 30° EQUAL SPACES APART.
RELIEVE
1/4 x45° CHAMFER
1/8 x45° CHAMFER
2.500 DIA.
5.688 DIA.
2.0
1.5
5.500
203 | 1 | 1020 C.S. | 10 1/2 DIA.
1-HSK-976
1/2 SIZE SCALE
(2) HOLES IN LINE .53 DIA.
1.530
.765
RAD.
4.0 STOCK
1.8 STOCK
1.25
2.0
5/8-11 THREAD
1 | C.R.S.-1020 | 1 1/2 x 5 x 4
1-HSK-976
SCALE 1/2 SIZE
RAD. T/M -207
4.0 STOCK
2.500 DIA.
5.815 RAD. (SPHERICAL)
4.397
2.0
11 1/4 STOCK
5.500
2.000 DIA.
1.500 DIA.
.03x45° MAX. CHAMFER TYP.
DR. 1/2 DIA. THRU & TAP 5/8-14 THD. x 5/8 MIN DP.
1 | H.R.S.-1020 | 4 x 4 x 11 1/4
1-HSK-976
SCALE 1/2 SIZE
1.8
1.5
.3
2"-12 UNF THD.
1.748 DIA.
3" DIA. STOCK
2 1/2 TYP FLAT
1.005 DIA. THRU
1 | H.R.S.-1020 | 3" DIA x 2 1/4
1-HSK-976
1/2 SIZE SCALE
.06 SAW CUT
3.0 DIA. STOCK
1.501 DIA.
.03x45 MAX. CHAMFER
.03 RELIEF
1.5
.900
2.500 DIA.
.06x45° CHAMFER
1 | C.R.S.-1020 | 3 DIA. x 1 1/2
2 PIECES WHEN SAWED APART.
1-HSK-976
SCALE 1/2 SIZE
1 | H.R.S.-1020 | 3x4x4
1 | WELD ASSY
1-HSK-976
SCALE 1/2 SIZE

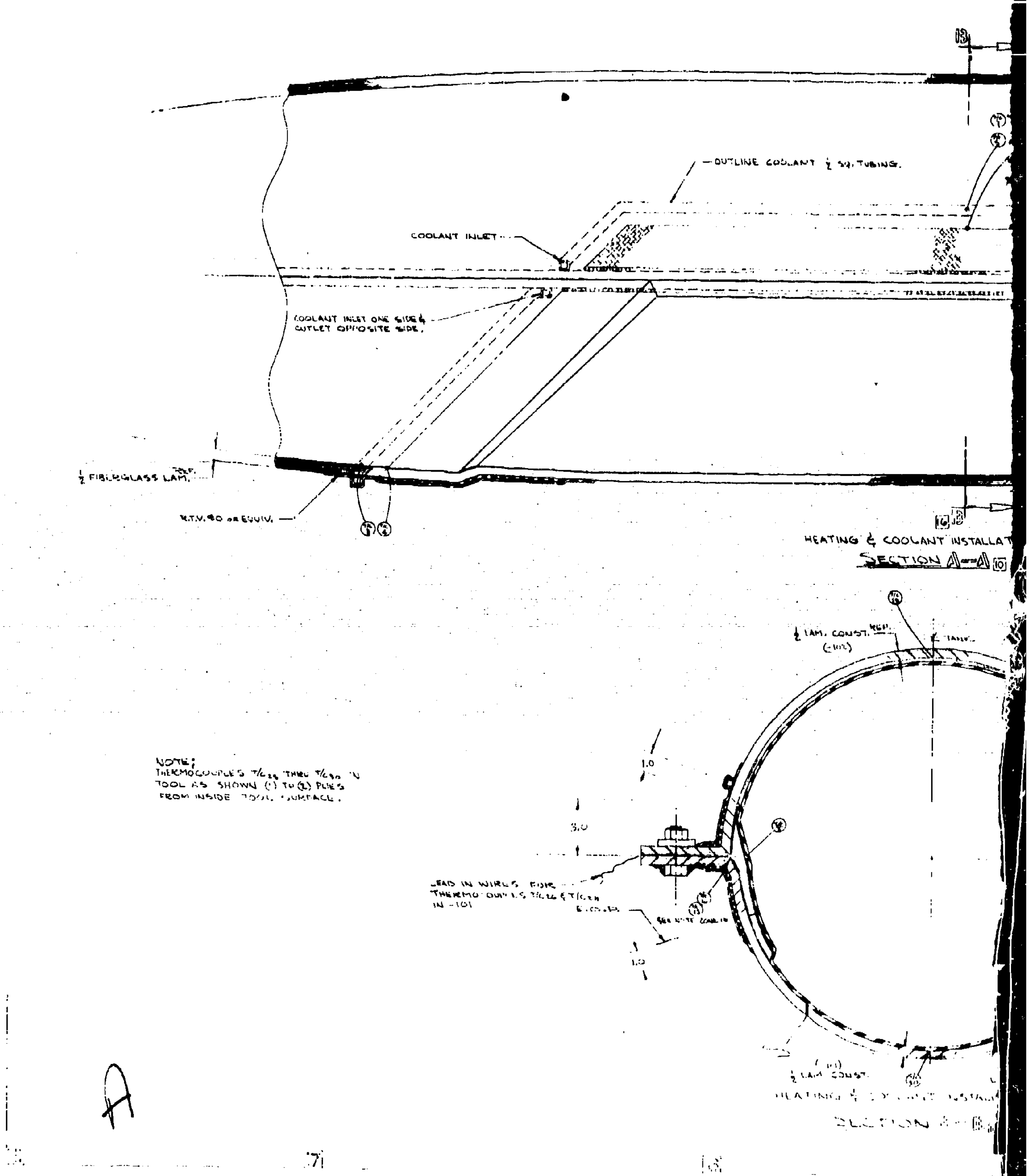
A

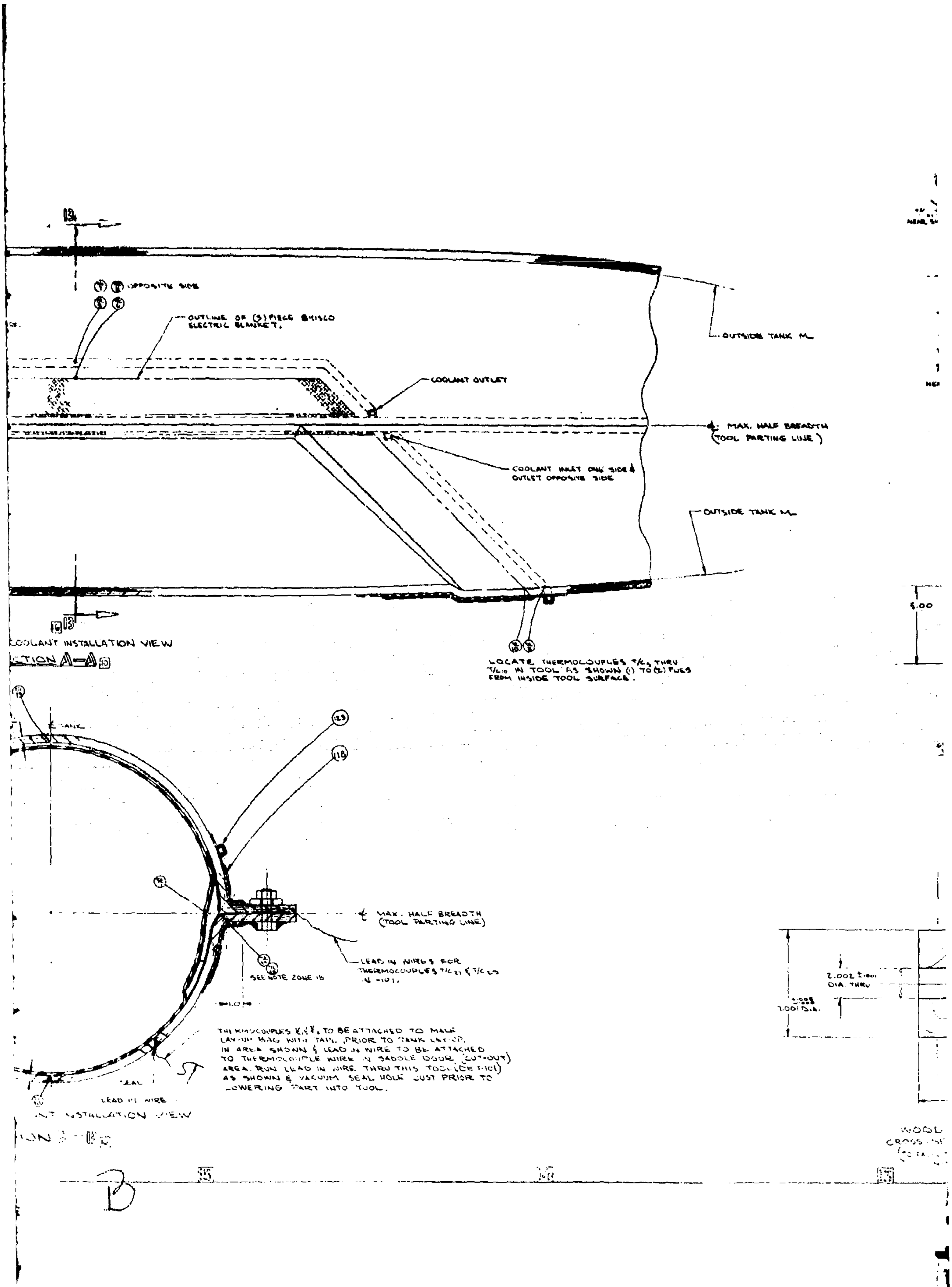


1-HSK-976
SCALE 1/2 SIZE
12" STOCK
.87 FLAT
1.0
DR. 1" DIA. (4) HOLES ON 30° EQUAL SPACES APART.
RELIEVE
3.246 DIA.
3.805 DIA.
6.00 RAD.
9.555 DIA.
8.688 DIA.
2.500 DIA.
1/8 x45° CHAMFER
5/8-11 THD. x 2.0 DEEP DO NOT DR. THRU TO 2" DIA. HOLE.
STAMP
2.0
1.5
4.0
5.500
NOTE: ALL EXTERNAL SURFACES 63
1-HSK-976
NON-STOCK
1/2 SIZE SCALE
4.597
2.000 DIA.
1.500 DIA.
.03 x45° MAX. CHAMFER
2.500 DIA
4.0 STOCK
1.748 DIA.
2"-12 UNF THD.
1.005 DIA. THRU
2 1/2 TYP FLAT
1-HSK-976
1/2 SIZE SCALE
RELIEVE .03
2 1/2-12 UNF THD.
4.0 TYP. FLAT
DRILL 1.010 DIA. THRU, C'BORE 1.752 DIA. TO .28 DIM. & THD 2"-12 UNF x 1.0 DP.
1-HSK-976
1/2 SIZE SCALE
4.00 DIA.
2 1/2-12 UNF THD.
1-HSK-976
1/2 SIZE SCALE
1/8 x45° CHAMFER
134.000
1-HSK-976
SCALE 1/2 SIZE
3
2

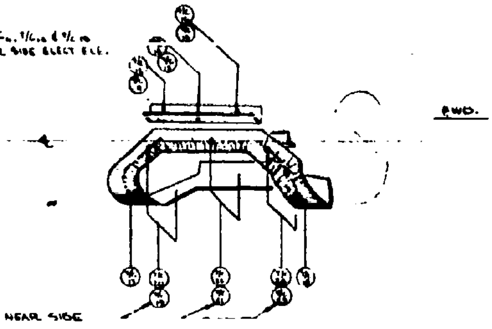


"Figure 67 Continued" Male Mandrel Forming Tower

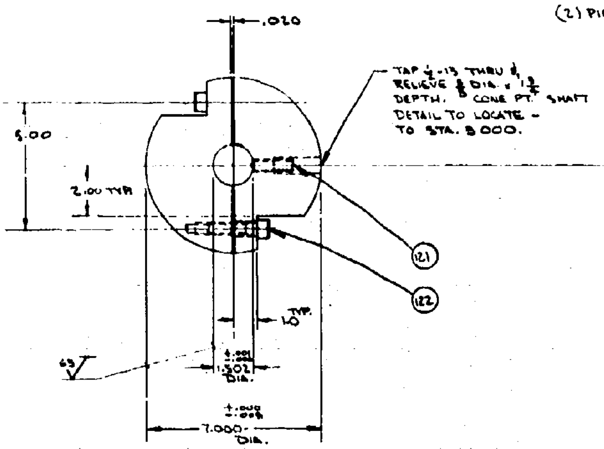

OUTLINE COOLANT 1/2 SQ. TUBING.
COOLANT INLET
COOLANT INLET ONE SIDE & OUTLET OPPOSITE SIDE.
1/2 FIBERGLASS LAM. TYP.
R.T.V. 90 OR EQUIV.
HEATING & COOLANT INSTALLAT
SECTION A-A
1/2 LAM. CONST. REF.
NOTE;
THERMOCOUPLES
IN TOOL AS SHOWN
FROM INSIDE TOOL SURFACE.
1.0
3.0
LEAD IN WIRES FOR
1/2 LAM. CONST.
A

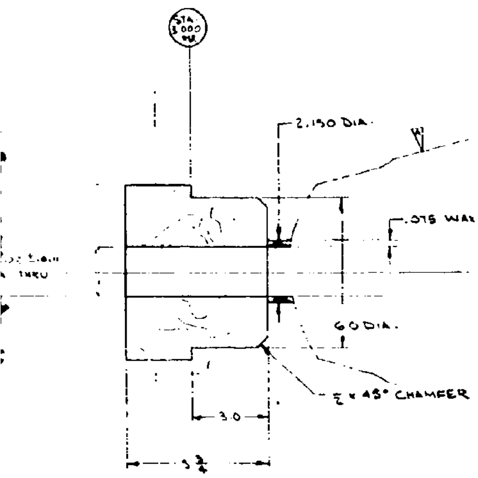


OPPOSITE SIDE
OUTLINE OF (3) PIECE BRISCO ELECTRIC BLANKET.
COOLANT OUTLET
OUTSIDE TANK ML
℄ MAX. HALF BREADTH (TOOL PARTING LINE)
COOLANT INLET ONE SIDE & OUTLET OPPOSITE SIDE
OUTSIDE TANK ML
COOLANT INSTALLATION VIEW
CTION A–A
LOCATE THERMOCOUPLES T/C THRU T/C IN TOOL AS SHOWN (1) TO (2) PLIES FROM INSIDE TOOL SURFACE.
5.00
℄ TANK
℄ MAX. HALF BREADTH (TOOL PARTING LINE)
LEAD IN WIRES FOR THERMOCOUPLES T/C & T/C IN -101.
SEE NOTE ZONE 15
THERMOCOUPLES TO BE ATTACHED TO MALE LAY-UP BAG WITH TAPE PRIOR TO TANK LAY-UP, IN AREA SHOWN & LEAD IN WIRE TO BE ATTACHED TO THERMOCOUPLE WIRE IN SADDLE DOOR (CUT-OUT) AREA. RUN LEAD IN WIRE THRU THIS TOOL (DET -101) AS SHOWN & VACUUM SEAL HOLE JUST PRIOR TO LOWERING PART INTO TOOL.
SEAL
LEAD IN WIRE
NT INSTALLATION VIEW
2.002 DIA. THRU
WOOD
B

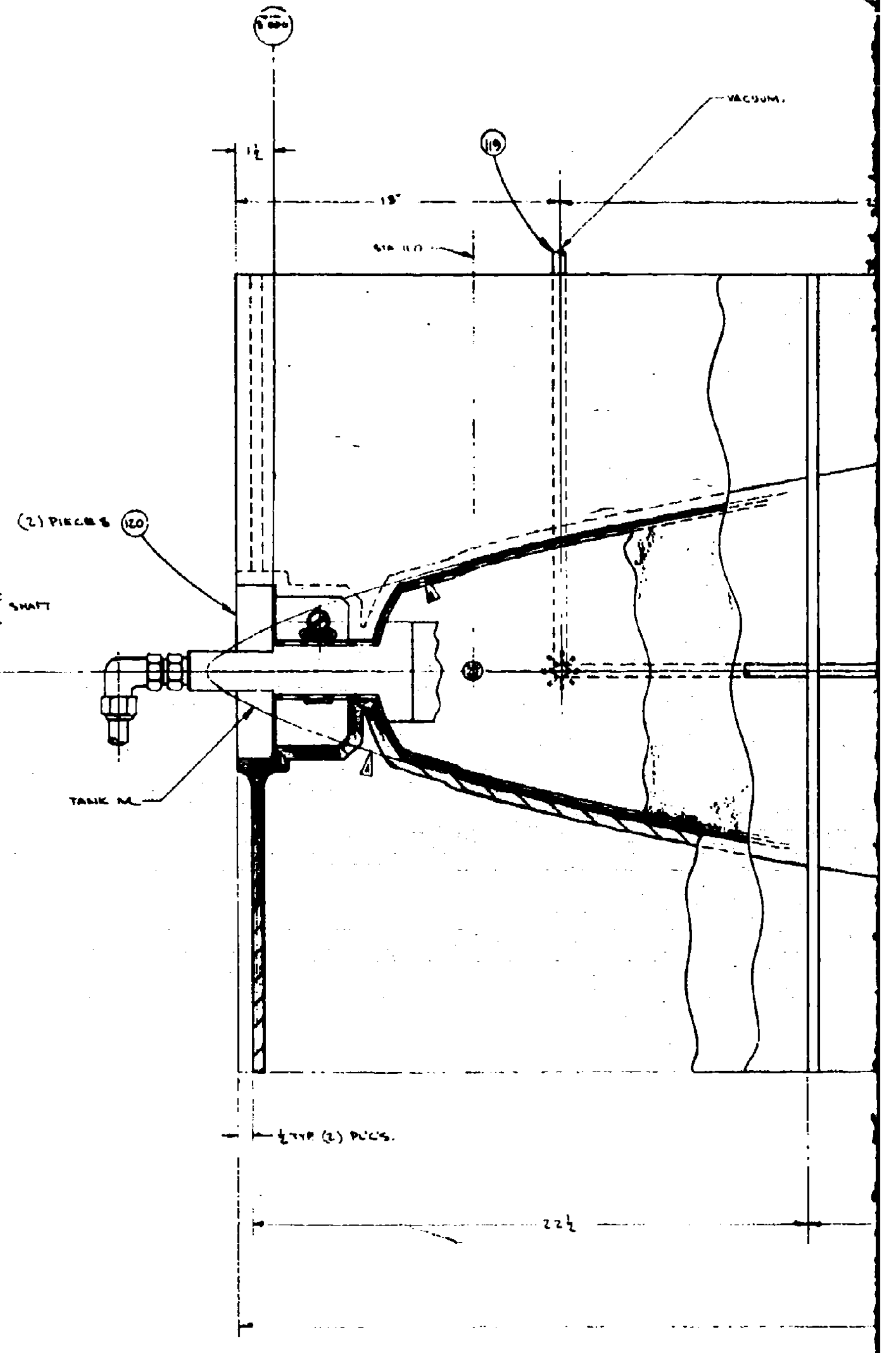


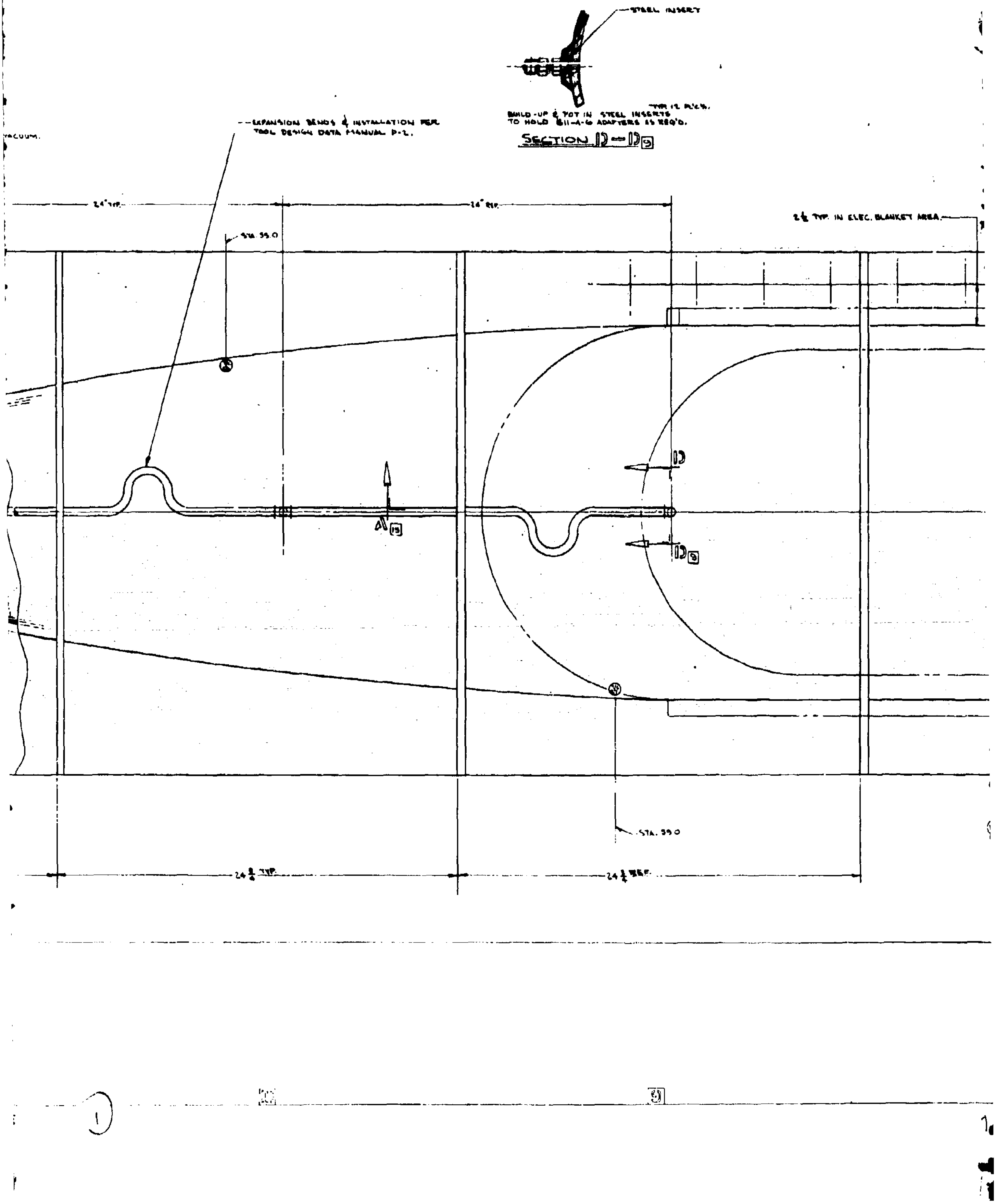
ELECTRIC ELEMENT THERMOCOUPLE
SCHEMATIC
(NO SCALE)

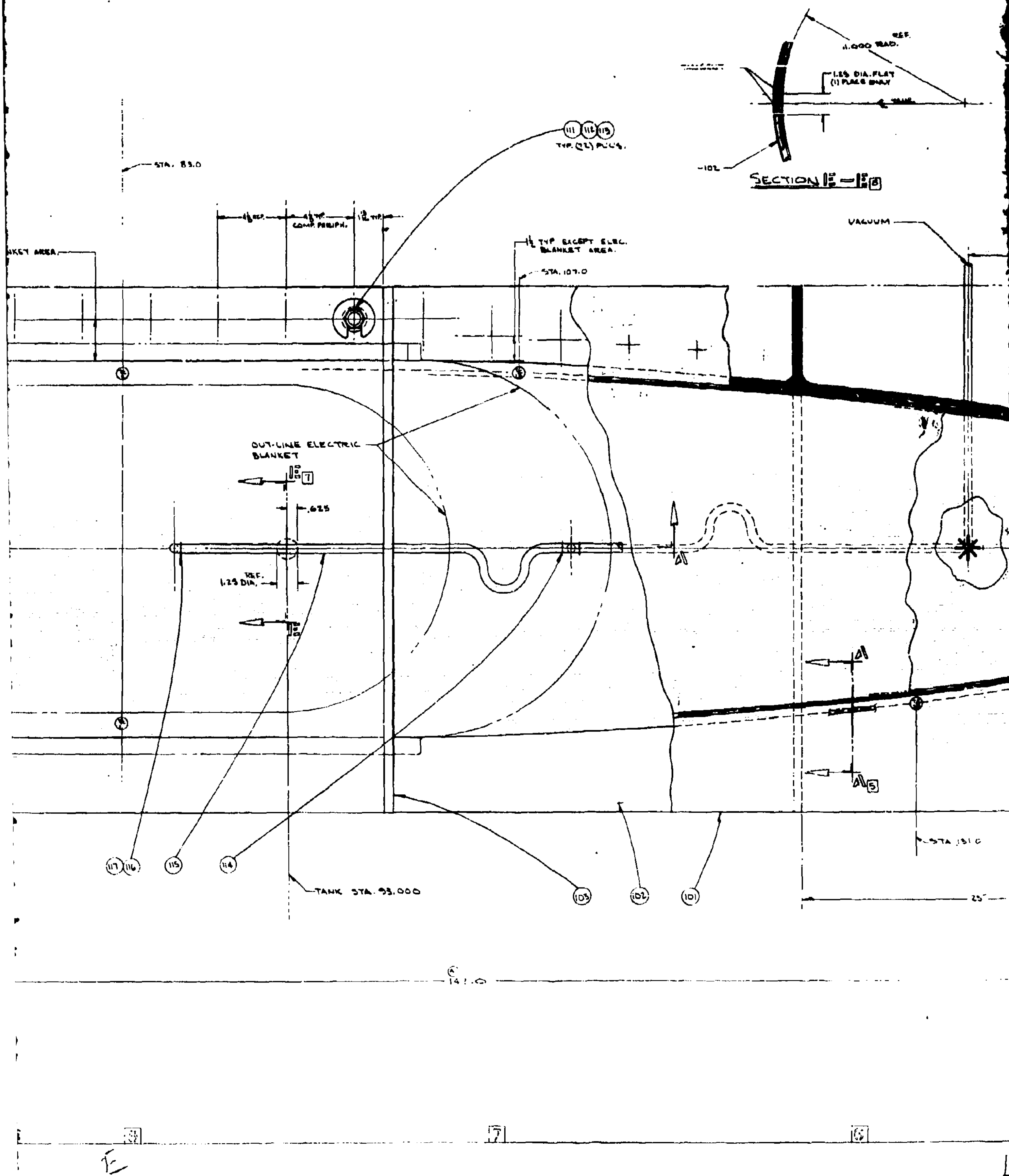




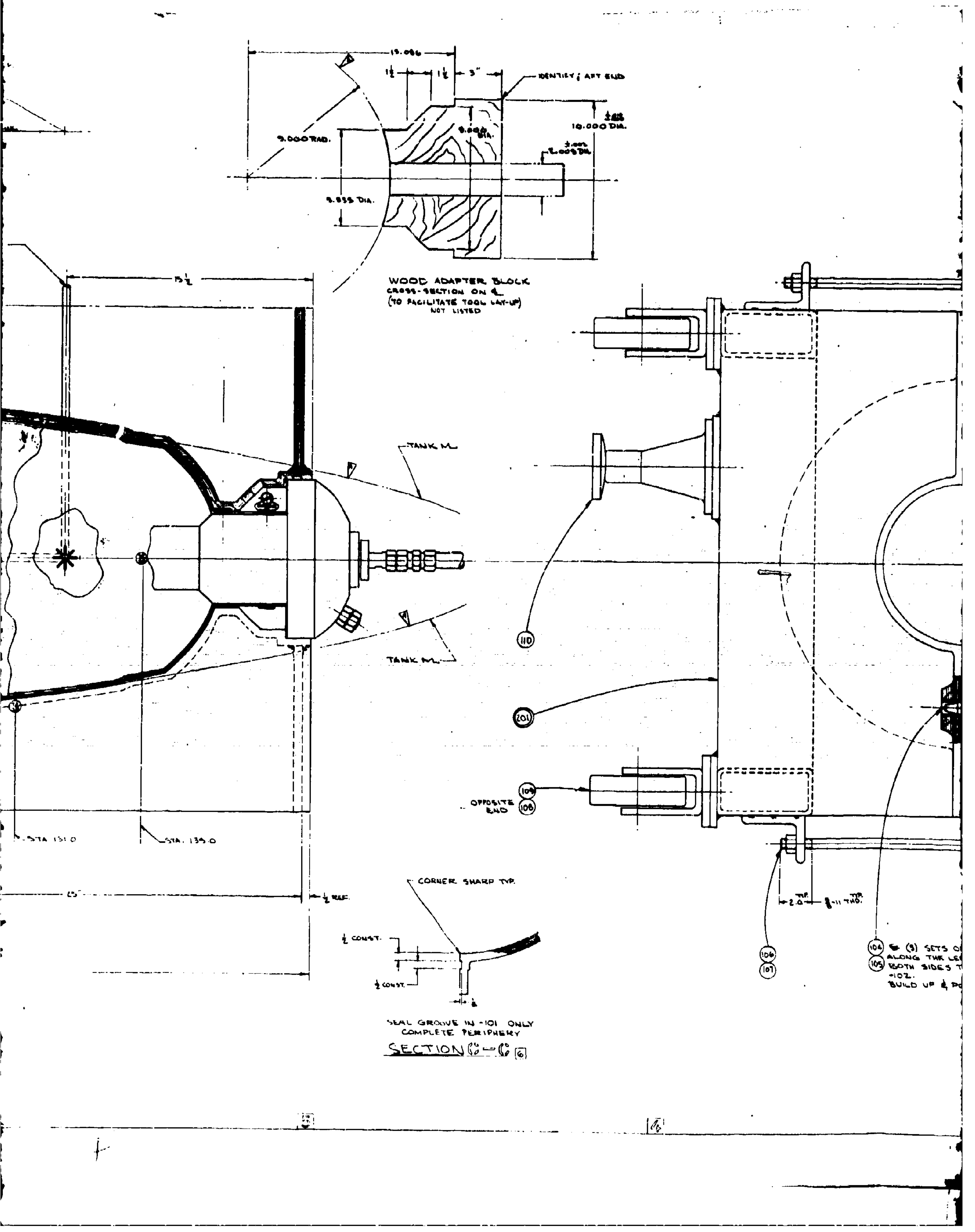
WOOD ADAPTER BLOCK
CROSS SECTION ON ℄



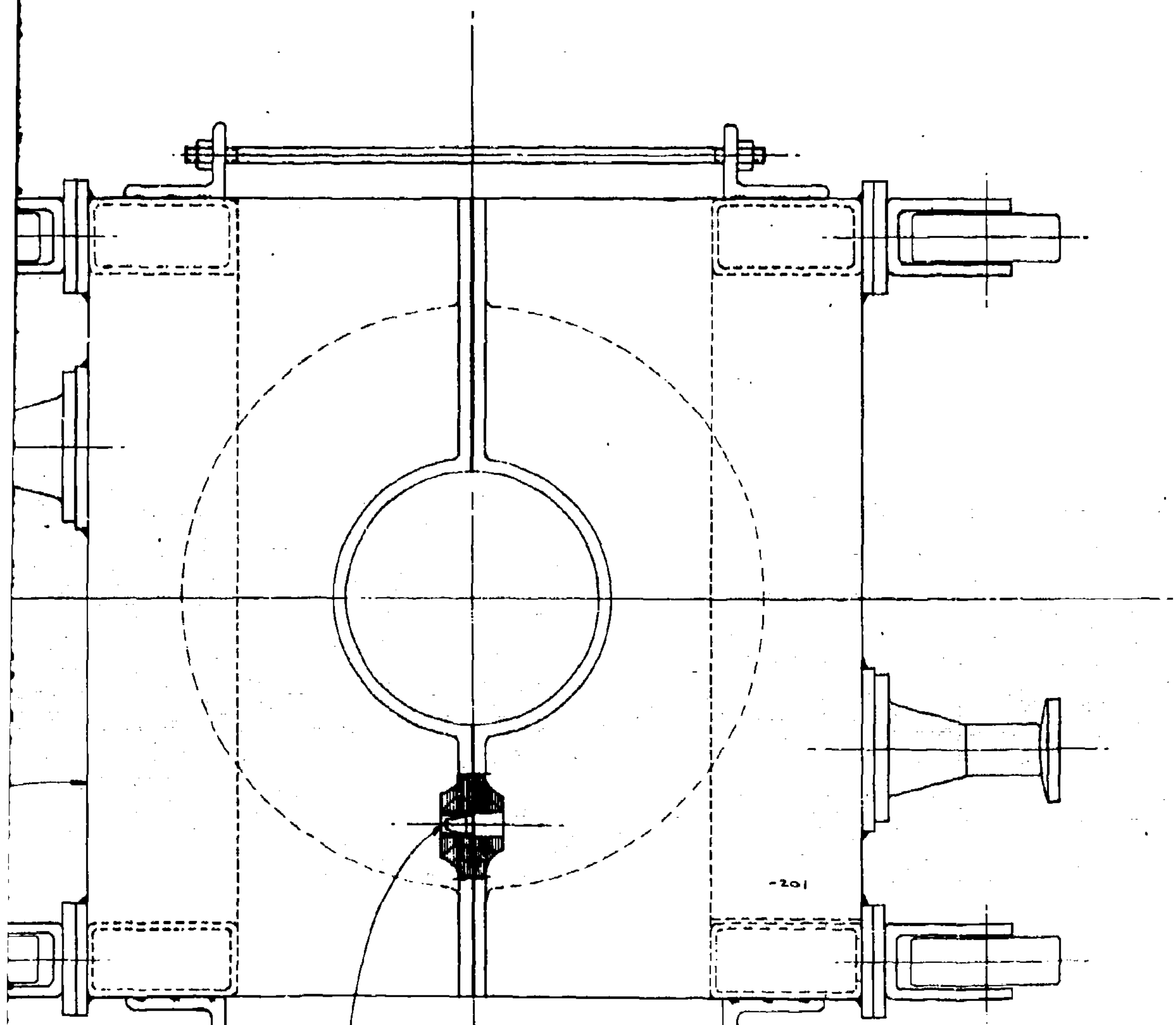

STEEL INSERT
TYP 12 PLC'S.
BUILD-UP & POT IN STEEL INSERTS TO HOLD 611-A-6 ADAPTERS AS REQ'D.
SECTION D—D 9
EXPANSION BENDS & INSTALLATION PER TOOL DESIGN DATA MANUAL P-2.
VACUUM.
24" TYP.
24" REF.
2½ TYP. IN ELEC. BLANKET AREA.
STA. 35.0
D
D 9
A 15
STA. 35.0
24 ¾ TYP.
24 ¼ REF.



11.000 RAD. REF.
1.25 DIA. FLAT (1) PLACE ONLY
-102
SECTION E-E
111 116 119 TYP. (22) PLCS.
STA. 83.0
COMP. PERIPH.
1 1/2 TYP EXCEPT ELEC. BLANKET AREA.
STA. 107.0
VACUUM
OUT-LINE ELECTRIC BLANKET
.625
REF. 1.25 DIA.
117 116 115 114 103 102 101
TANK STA. 93.000
STA. 131.0
25
141.0
8
7
6
E



WOOD ADAPTER BLOCK
CROSS-SECTION ON ℄
(TO FACILITATE TOOL LAY-UP)
NOT LISTED
IDENTIFY ℄ AFT END
9.000 RAD.
10.000 DIA.
TANK M.L.
OPPOSITE END
STA. 131.0
STA. 139.0
CORNER SHARP TYP.
SEAL GROOVE IN -101 ONLY
COMPLETE PERIPHERY
SECTION



104 6 (3) SETS OF PINS & BUSHINGS
105 ALONG THE LENGTH OF TOOL, TYP. BOTH SIDES TO C/D DET'S-101 & -102.
BUILD UP & POT IN AS REQ'D.

HSK-986 P.M.U.
C/D TOOLS;

3 - MAY BE PURCHASED FROM; THE
1055 GIBBARD AVE. COLUMBU
2 - MAY BE PURCHASED FROM; SC
6473 PROPRIETORS RD. BOX 23
1 - MAY BE PURCHASED FROM. WILL
WILLIAMS AVE. COLUMBUS, OH

GENERAL N

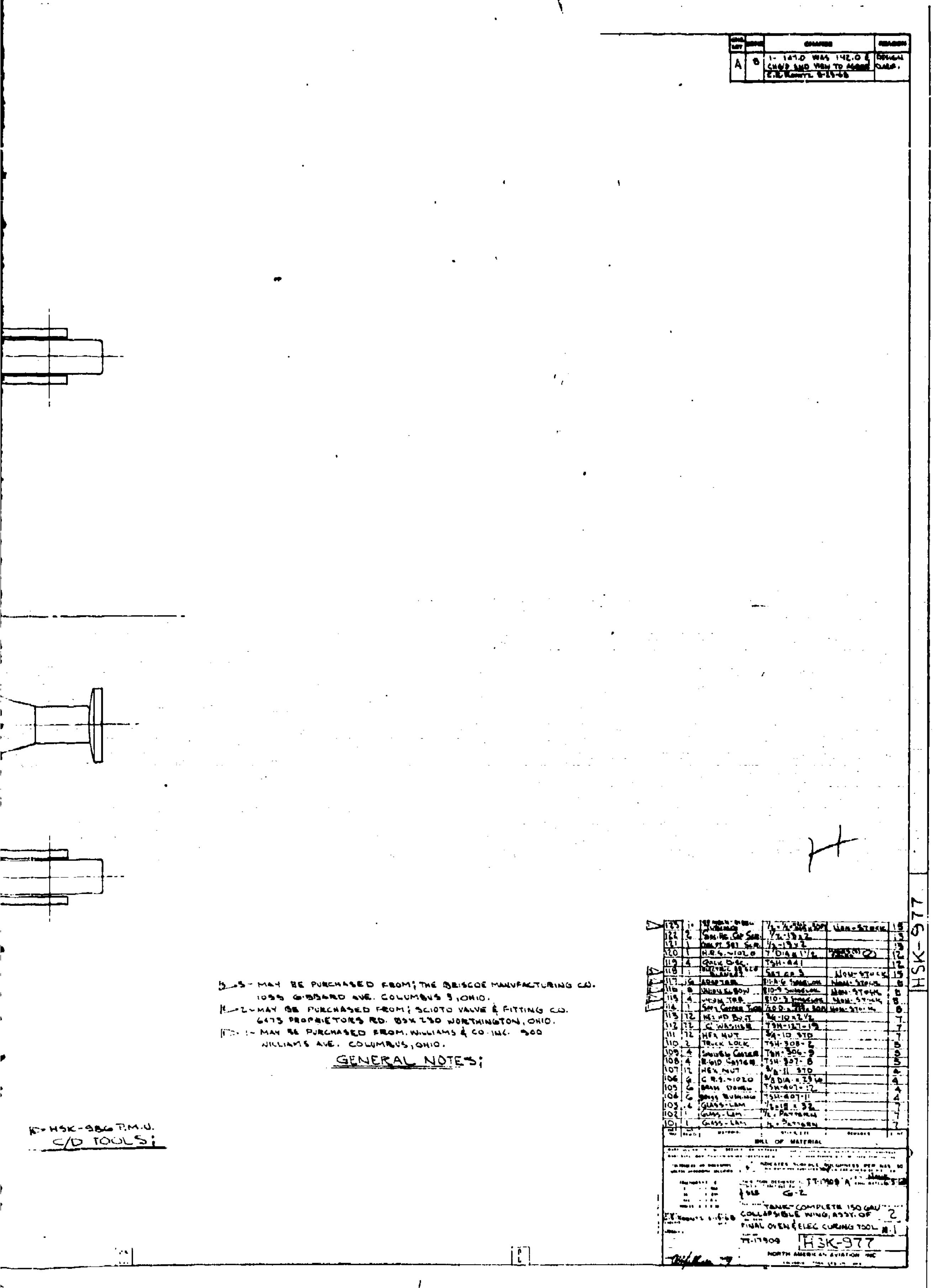
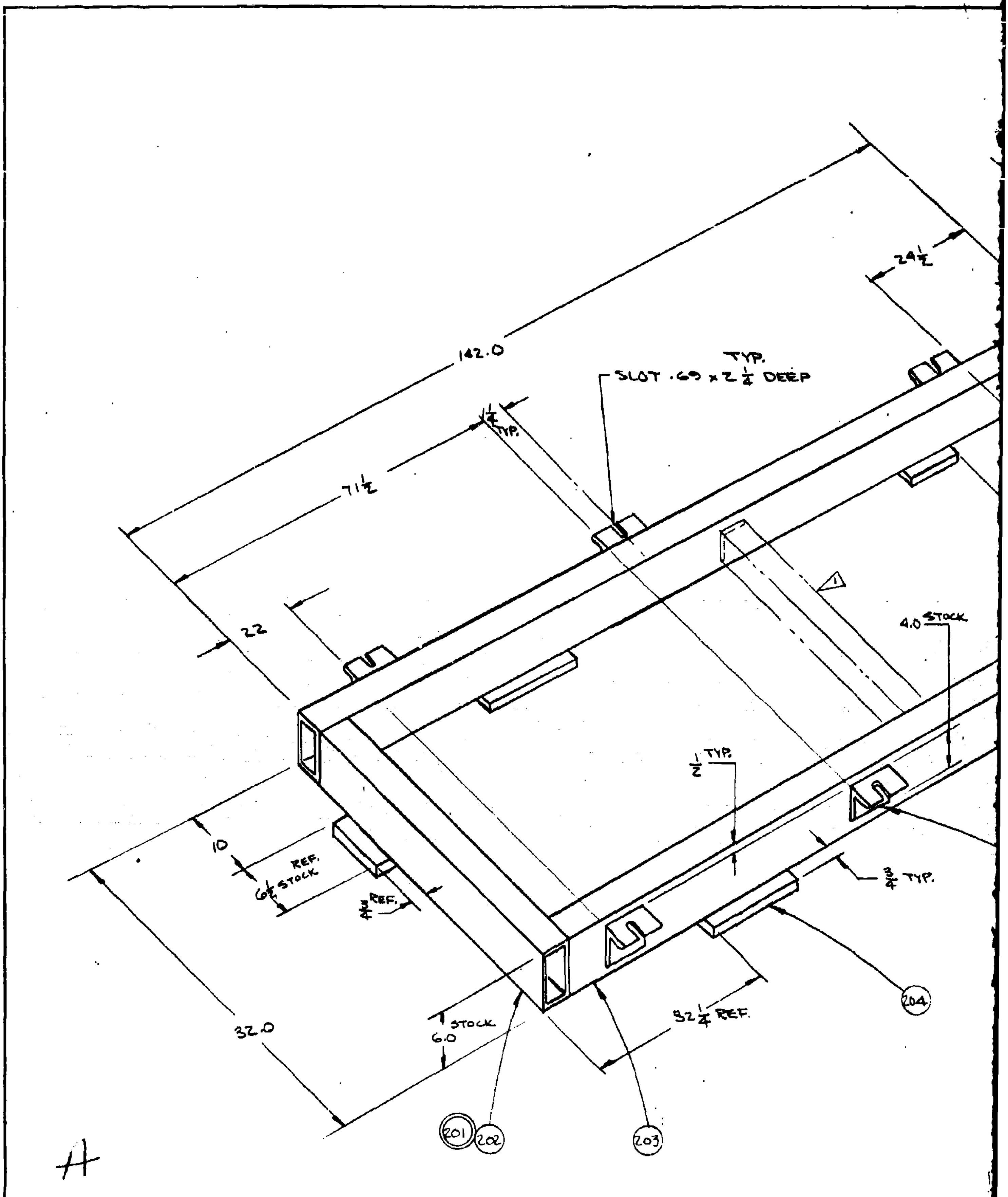


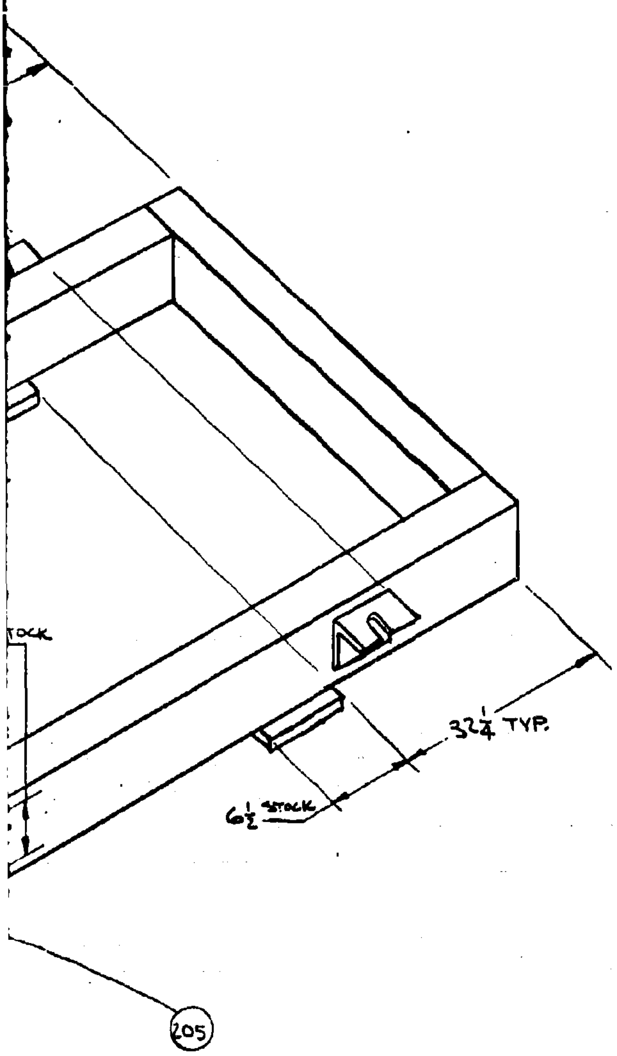
Figure 68 Final Female Curing Tool



142.0
24 1/2
TYP.
SLOT .69 x 2 1/4 DEEP
1/4 TYP.
71 1/2
22
4.0 STOCK
1/2 TYP.
10
REF.
6 1/4 STOCK
3/4 REF.
3/4 TYP.
32 1/4 REF.
204
6.0 STOCK
32.0
201
202
203
A

HSK-977

CHG. LET.	CHANGE	REASON



▷1- ASSEMBLY TO BE REINFORCED WITH STD. STEEL ANGLES AS REQ'D. AT ASSY.

NOTE:

DET. NO.	NO. REQ'D.	MATERIAL	STOCK SIZE	REMARKS
205	6	STL. ANGLE	$4 \times 3 \times 1/2 \times 2\,1/2$	
204	5	H.R.S.-1020	$1/2 \times 4\,1/2 \times 6\,1/2$	
203	2	RECT. STL. TUBE	$6 \times 3 \times .375 \times 139$	
202	2	RECT. STL. TUBE	$6 \times 3 \times .375 \times 29$	
201	2	WELD ASSY.		

BILL OF MATERIAL

MARK TOOL NO. ON TOOL | BREAK ALL ROUGH EDGES | FOR ALL REPLACEMENT DETAILS WITH FIT DIMENSIONS ACTUAL MEASUREMENTS MUST BE TAKEN FROM THE JOB

MARK MAT'L. IDENTIFICATION ON HEAT-TREATED DETS.

TOLERANCES ON DIMENSIONS UNLESS OTHERWISE SPECIFIED

FRACTIONS = ± 1/16
.X = ± .060
.XX = ± .030
.XXX = ± .010
ANGLES = ± 0°30'

√ INDICATES SURFACE ROUGHNESS PER NAS 30 (ALL MACHINED SURFACES 125√ UNLESS OTHERWISE SPECIFIED)

THIS TOOL DESIGNED TO _______ E.O. _______ CHG. DATED _______

SCALE: NONE

DRAWN: C.E. KOONTZ 6-24-68

SEE SHT. JR-1

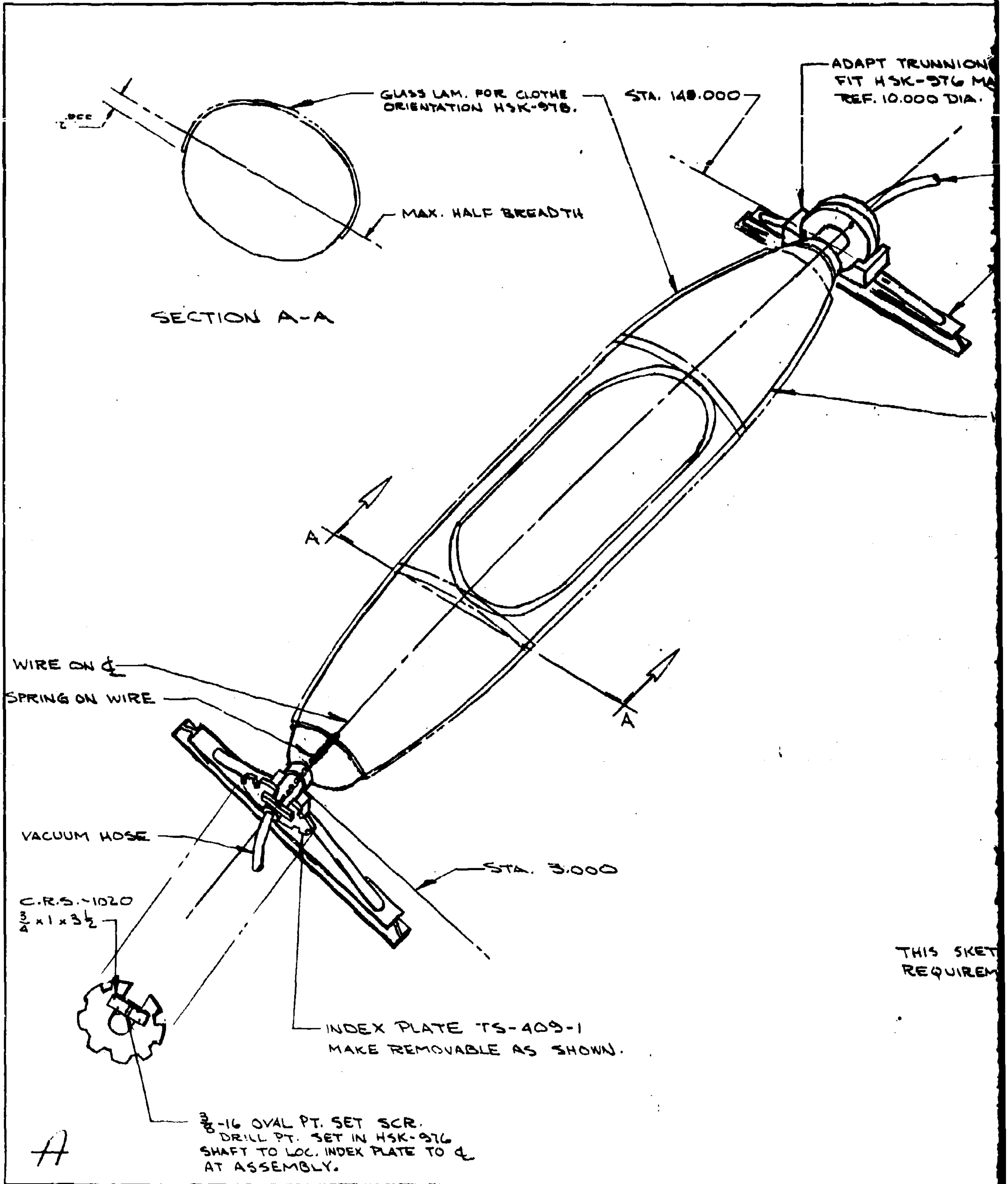
SHEET NO. G-2

TOOL NO. HSK-977

COLUMBUS DIVISION
NORTH AMERICAN ROCKWELL CORPORATION

B

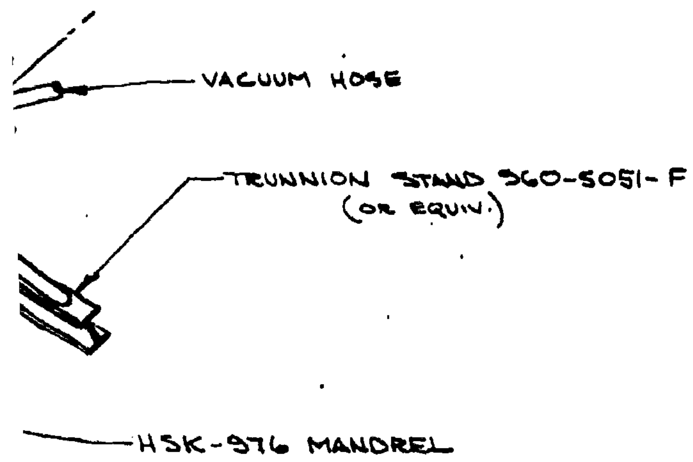
"Figure 68 Continued" Final Female Curing Tool


GLASS LAM. FOR CLOTHE
ORIENTATION HSK-978.
STA. 148.000
ADAPT TRUNNION
FIT HSK-976 MA
REF. 10.000 DIA.
MAX. HALF BREADTH
SECTION A-A
A
A
WIRE ON ℄
SPRING ON WIRE
VACUUM HOSE
STA. 3.000
C.R.S.-1020
3/4 x 1 x 3 1/2
INDEX PLATE TS-409-1
MAKE REMOVABLE AS SHOWN.
3/8-16 OVAL PT. SET SCR.
DRILL PT. SET IN HSK-976
SHAFT TO LOC. INDEX PLATE TO ℄
AT ASSEMBLY.
THIS SKET
REQUIREM

HSK-980

CHG. LTR.	CHANGE	REASON

TRUNNION END TO
K-976 MANDREL END.
.000 DIA.



B

S SKETCH FURNISHED TO SHOW ADAPTER
QUIREMENTS FOR ENDS OF SUPPORT DOLLY.

GENERAL NOTES;

DET. NO.	NO. REQ'D	MATERIAL	STOCK SIZE	REMARKS

BILL OF MATERIAL

TOLERANCES ON DIMENSIONS UNLESS OTHERWISE SPECIFIED
FRACTIONS = ± 1/64
.X = ± .060
.XX = ± .030
.XXX = ± .010
ANGLES = ± 0°30'

INDICATES SURFACE ROUGHNESS PER NAS 30

THIS TOOL DESIGNED TO T-17909 E.O. NONE CHG. DATED

NONE

PART NAME: TANK-COLLAPSIBLE WING ASSY, OF (TEST) — TOTAL SHTS 1

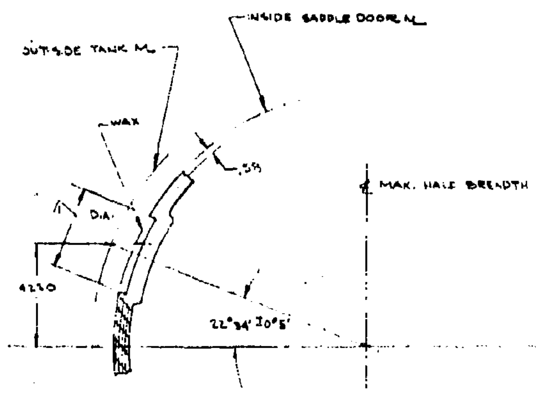
TOOL NAME: SUPPORTING DOLLY — G-1

PART NO. TT-17909 — TOOL NO. HSK-980

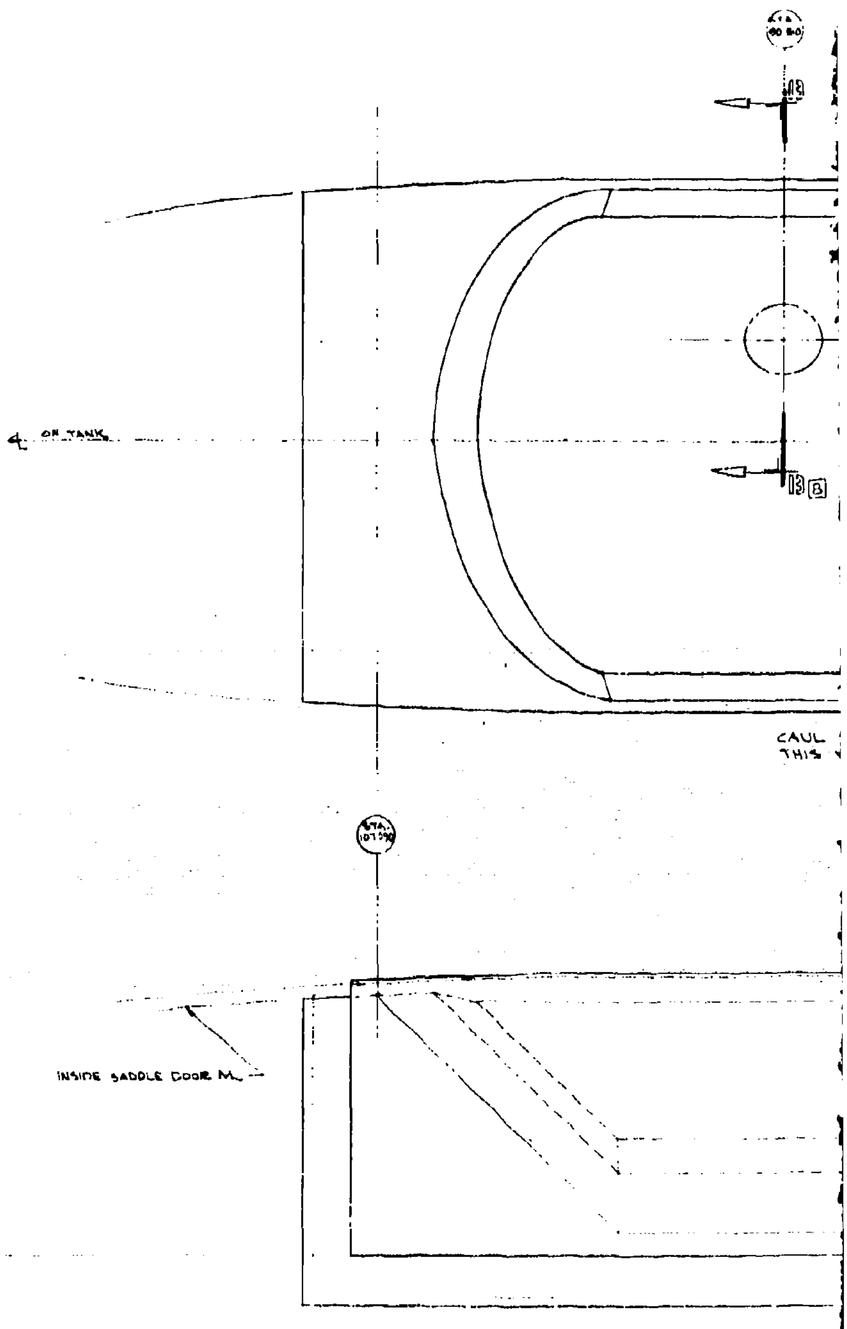
C.B. KOONTZ

COLUMBUS DIVISION
NORTH AMERICAN ROCKWELL CORPORATION

Figure 69 Supporting Dolly for Female Tool

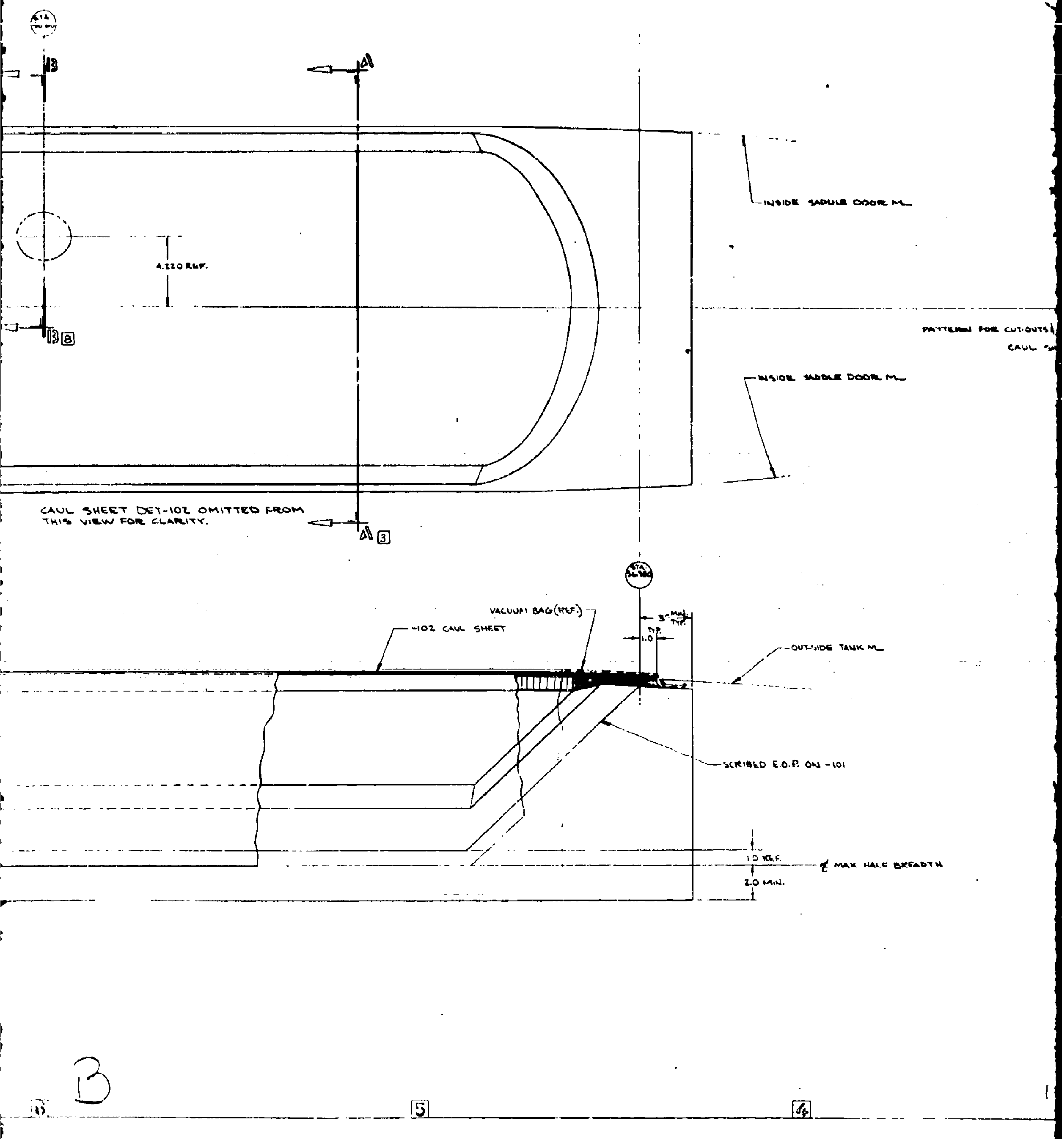


SECTION B-B

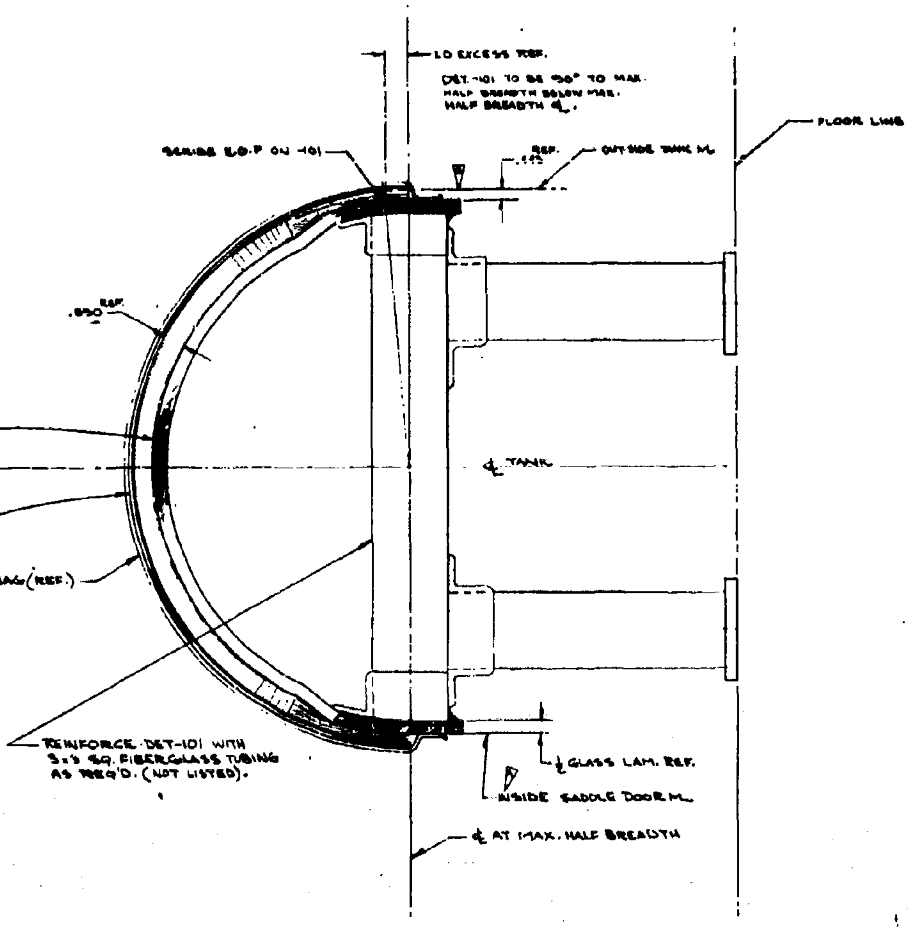


A

7



INSIDE SADDLE DOOR ML
4.220 REF.
PATTERN FOR CUT-OUTS
INSIDE SADDLE DOOR ML
CAUL SHEET DET-102 OMITTED FROM THIS VIEW FOR CLARITY.
STA.
VACUUM BAG (REF.)
-102 CAUL SHEET
3" MIN. TYP.
TYP. 1.0
OUTSIDE TANK ML
SCRIBED E.O.P. ON -101
1.0 REF.
℄ MAX HALF BREADTH
2.0 MIN.
B
5
4



SECTION A — A 6

1 - THIS DIA TO BE A LOOSE S.F. FOR HE-193- ADAPTER FROM HE-193-8002-0007 CAP ASSY. W MEASUREMENT BEING TAKEN FROM PART.

GENERAL NOTES:

HSK-986 P.M.U.
SPLASH FROM HSK-975 (OPER. 7-E).
C/D INFO.

C

3 2

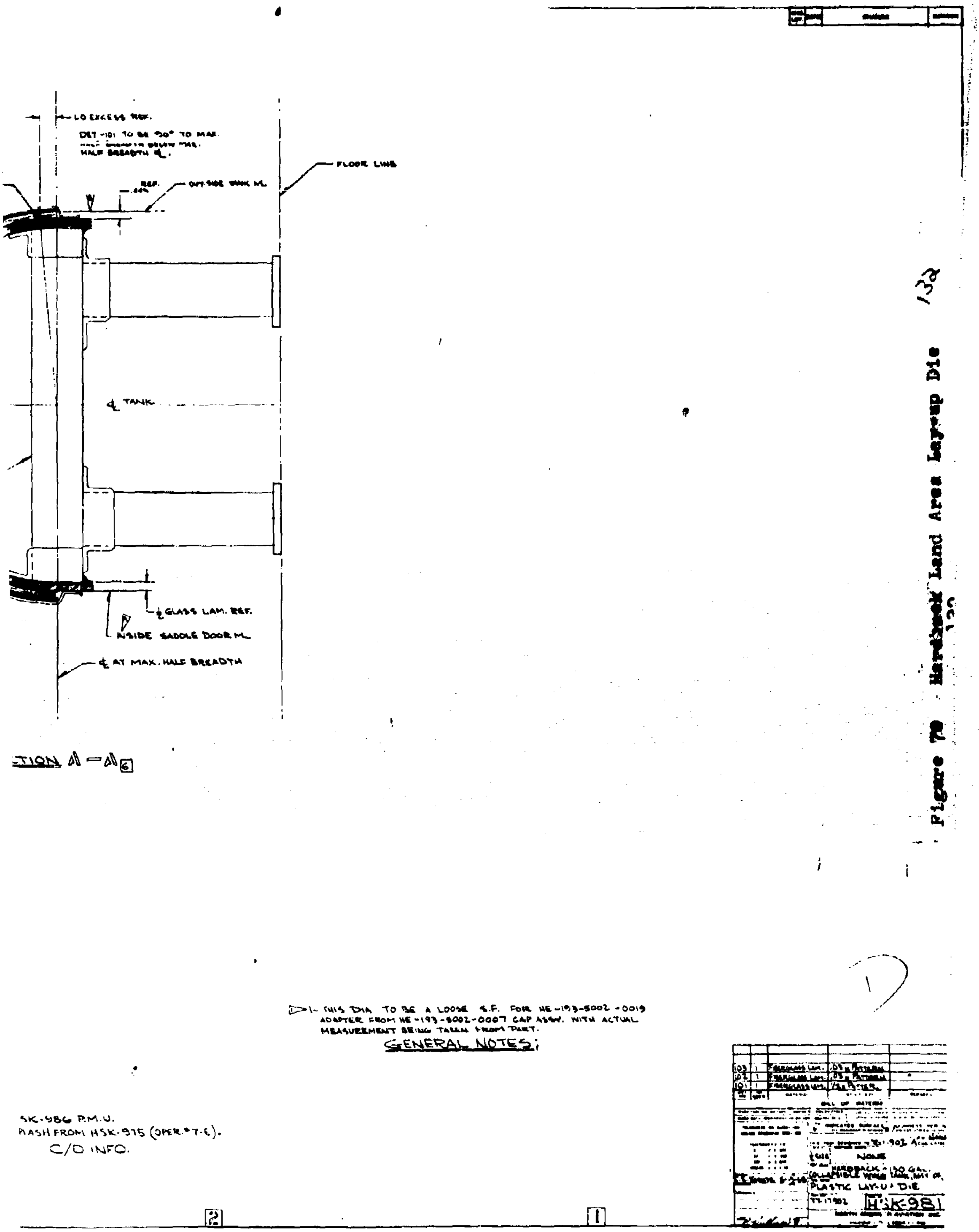
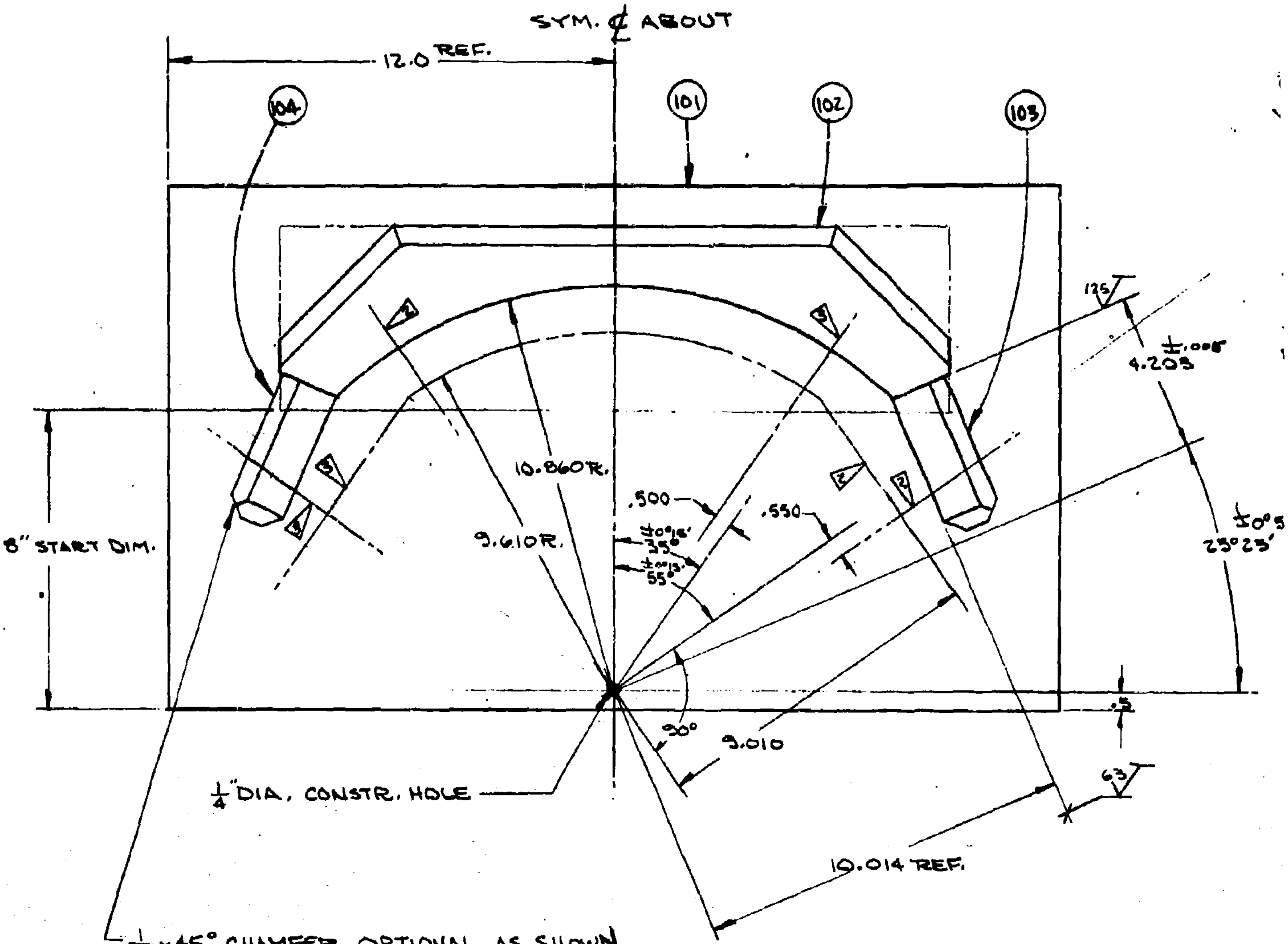
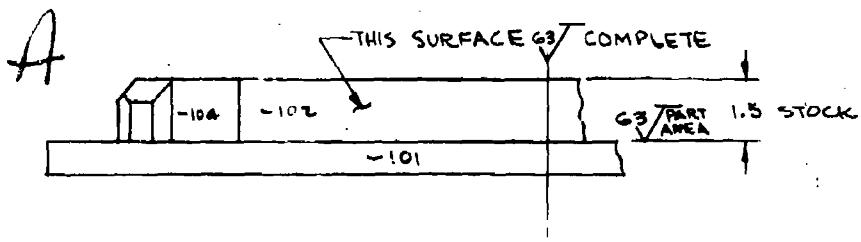


Figure 78 Hardback Land Area Layup Die





4-THIS TOOL MAK

3 - SCRIBE & IDEN

2 - SCRIBE & IDEN

1- SCREW & DOW

GE

HSK-983

CHG. LTR.	CHANGE	REASON

TOOL MAKES BOTH L.H. & R.H. PARTS.
IBE & IDENTIFY AS E.O.P. OF TT-17904-4
IBE & IDENTIFY AS E.O.P. OF TT-17904-3
EW & DOWEL CONSTRUCTION.

GENERAL NOTES:

DET. NO.	NO. REQ'D.	MATERIAL	STOCK SIZE	REMARKS
104	1	[illegible] ALUM. PLATE	1 1/2 x 1 1/2 x 4	
103	1	↓	1 1/2 x 1 1/2 x 4	
102	1	↓	1 1/2 x 5 x 18	
101	1	[illegible] ALUM. PLATE	3/4 x 14 x 24	

BILL OF MATERIAL

MARK TOOL NO. ON TOOL — BREAK ALL ROUGH EDGES — MARK MAT'L. IDENTIFICATION ON HEAT-TREATED DETS — FOR ALL REPLACEMENT DETAILS WITH FIT DIMENSIONS ACTUAL MEASUREMENTS MUST BE TAKEN FROM THE JOB

TOLERANCES ON DIMENSIONS UNLESS OTHERWISE SPECIFIED
FRACTIONS = ± 1/64
.X = ± .060
.XX = ± .030
.XXX = ± .010
ANGLES = ± 0°30'

✓ INDICATES SURFACE ROUGHNESS PER NAS 30 (ALL MACHINED SURFACES [illegible] UNLESS OTHERWISE SPECIFIED)

THIS TOOL DESIGNED TO TT-17904 'A' E.O. NONE CHG.-DATE

SCALE: 1/2 SIZE — ADDITIONAL SHEETS: NONE

PART NAME: CLIP-BULKH'D. COLLAPSIBLE WING TANK (TEST) — TOTAL REQ'D: 1

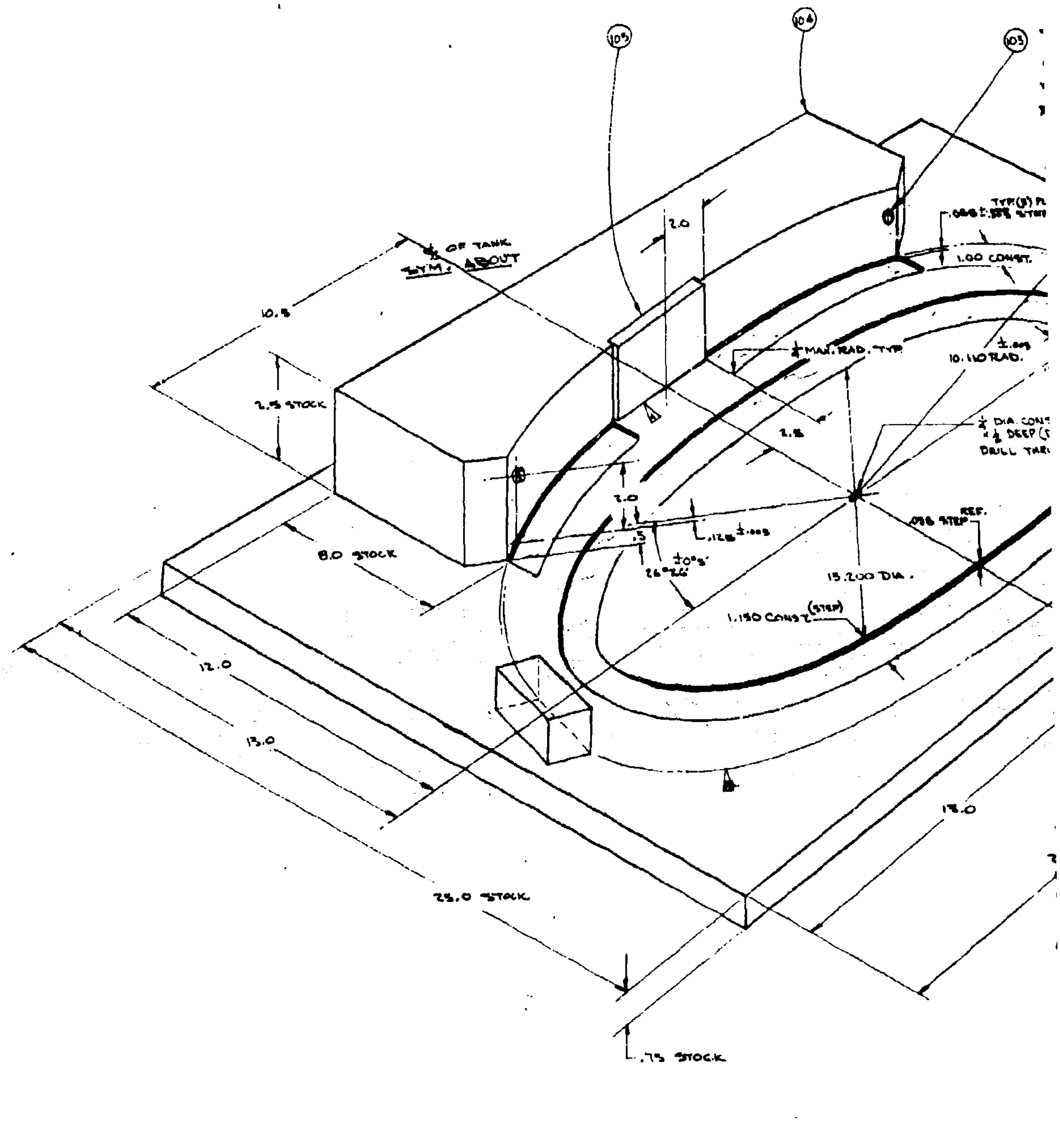
TOOL NAME: LAY-UP DIE — SHEET NO.: G-1

DRAWN: C. KOONTZ 6-9-68
CHECKED:
APPROVALS:

PART NO.: TT-17904-3-4 — TOOL NO.: HSK-983

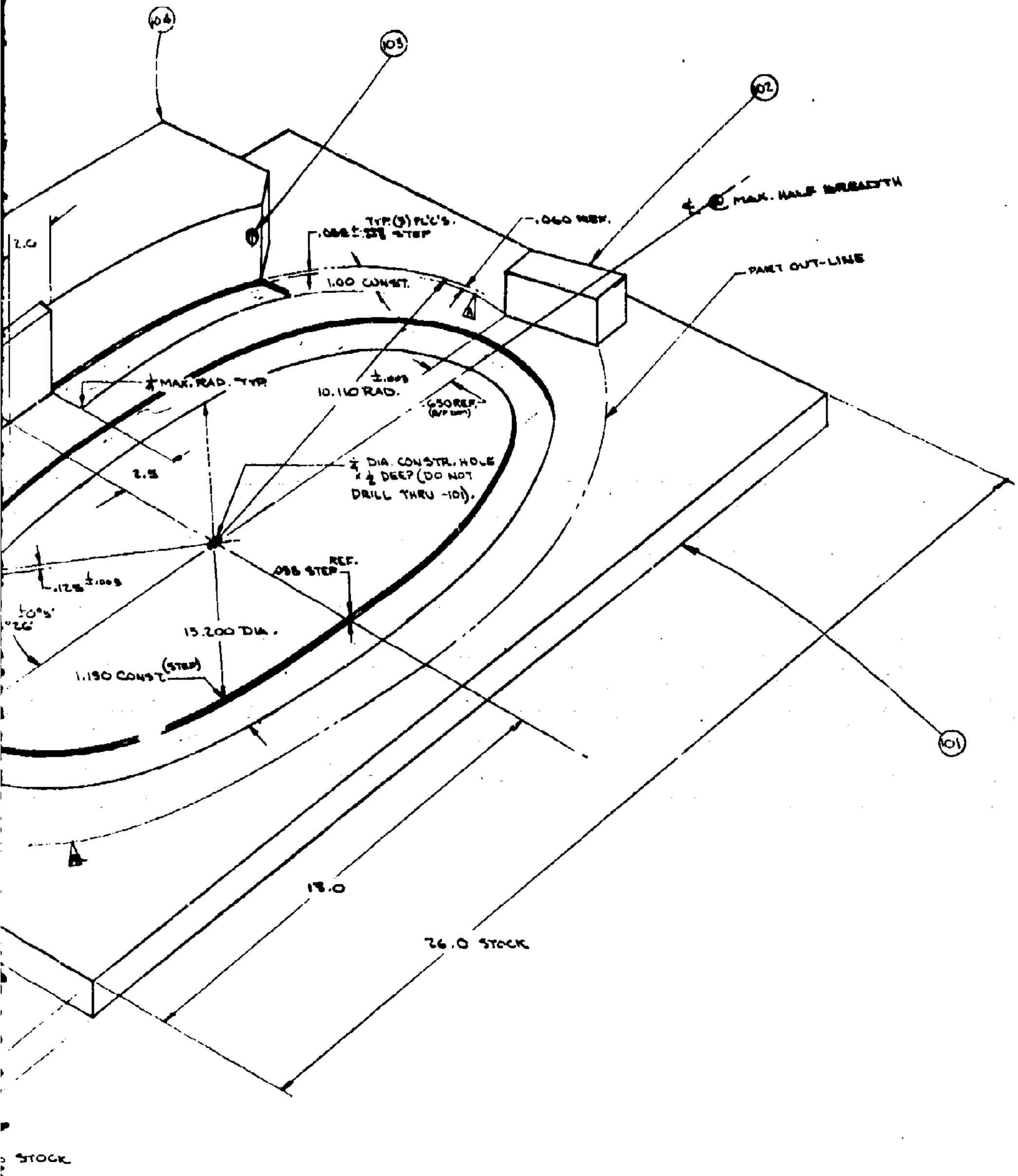
NORTH AMERICAN AVIATION, INC.
COLUMBUS — TOOL DESIGN — OHIO

Figure 71 Bulkhead Clip Lay-up Die



105
104
103
℄ OF TANK
SYM. ABOUT
10.5
2.0
2.5 STOCK
8.0 STOCK
¼ MAX. RAD. TYP.
10.110 RAD.
1.00 CONST.
2.5
2.0
.5
.125 ±.005
±0°5'
26°26'
15.200 DIA.
1.150 CONST. (STEP)
12.0
13.0
13.0
25.0 STOCK
.75 STOCK

[6] [5] [4]



3- REMOVE ALL SHARP EDGES & CORNERS FOR BAGGING OF PART PRIOR TO BOND

2- ALL SURFACES CONTACTING ENG. PART

1- SCREW & DOWEL CONSTRUCTION.

GENERAL NOTES:

1-372023 J.T.

C/D TOOLS

3- REMOVE ALL SHARP EDGES & CORNERS SUITABLE FOR BAGGING OF PART PRIOR TO BOND OPERATION.

2- ALL SURFACES CONTACTING ENG. PART TO BE 125√.

1- SCREW & DOWEL CONSTRUCTION.

GENERAL NOTES:

2

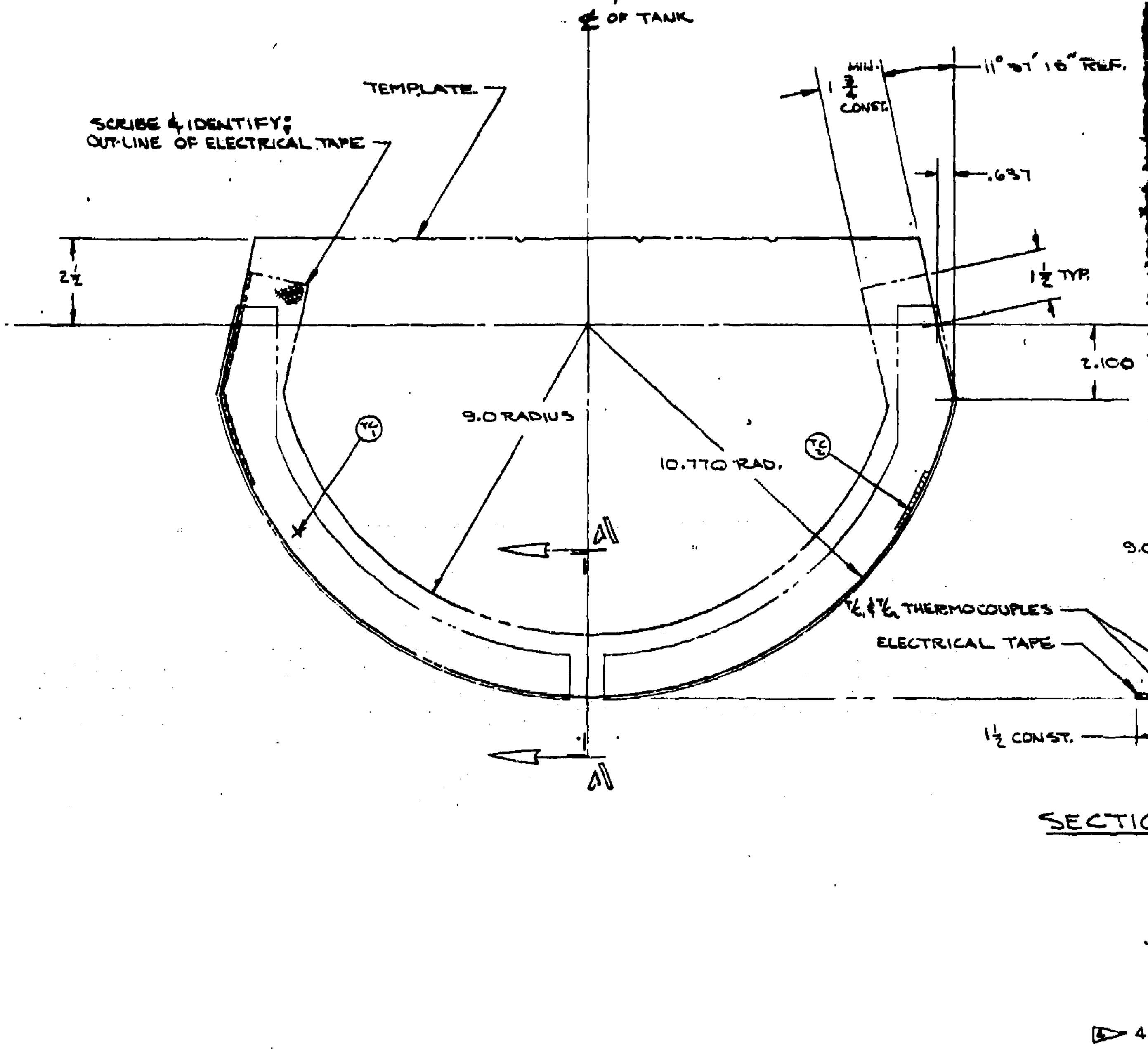
1

MATERIAL	
NONE	
BULKHEAD - COLLAPSIBLE WING TANK, ASSY OF (TEST)	1
BONDING JIG	
11-17905	HSK-984
NORTH AMERICAN ROCKWELL CORPORATION	

HSK-984

Figure 72 Bulkhead Bonding Jig

134



℄ OF TANK
TEMPLATE
SCRIBE & IDENTIFY;
OUT-LINE OF ELECTRICAL TAPE
MIN.
$1\frac{3}{4}$
CONST.
11° 37' 18" REF.
.637
$2\frac{1}{2}$
$1\frac{1}{2}$ TYP.
2.100
9.0 RADIUS
10.770 RAD.
TC 1
TC 2
A
TC₁ & TC₂ THERMOCOUPLES
ELECTRICAL TAPE
$1\frac{1}{2}$ CONST.
9.0
SECTIO
4
3
2

A

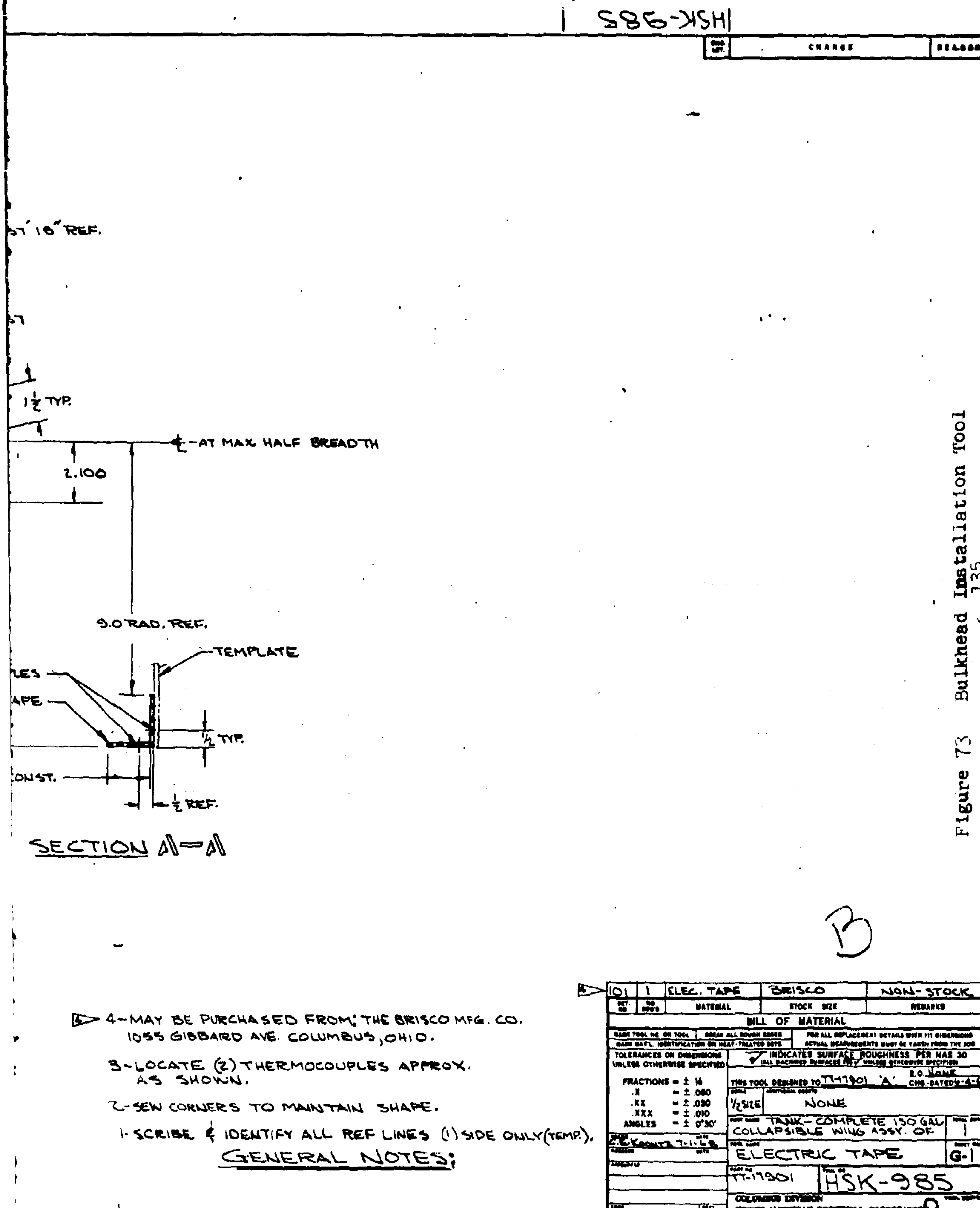
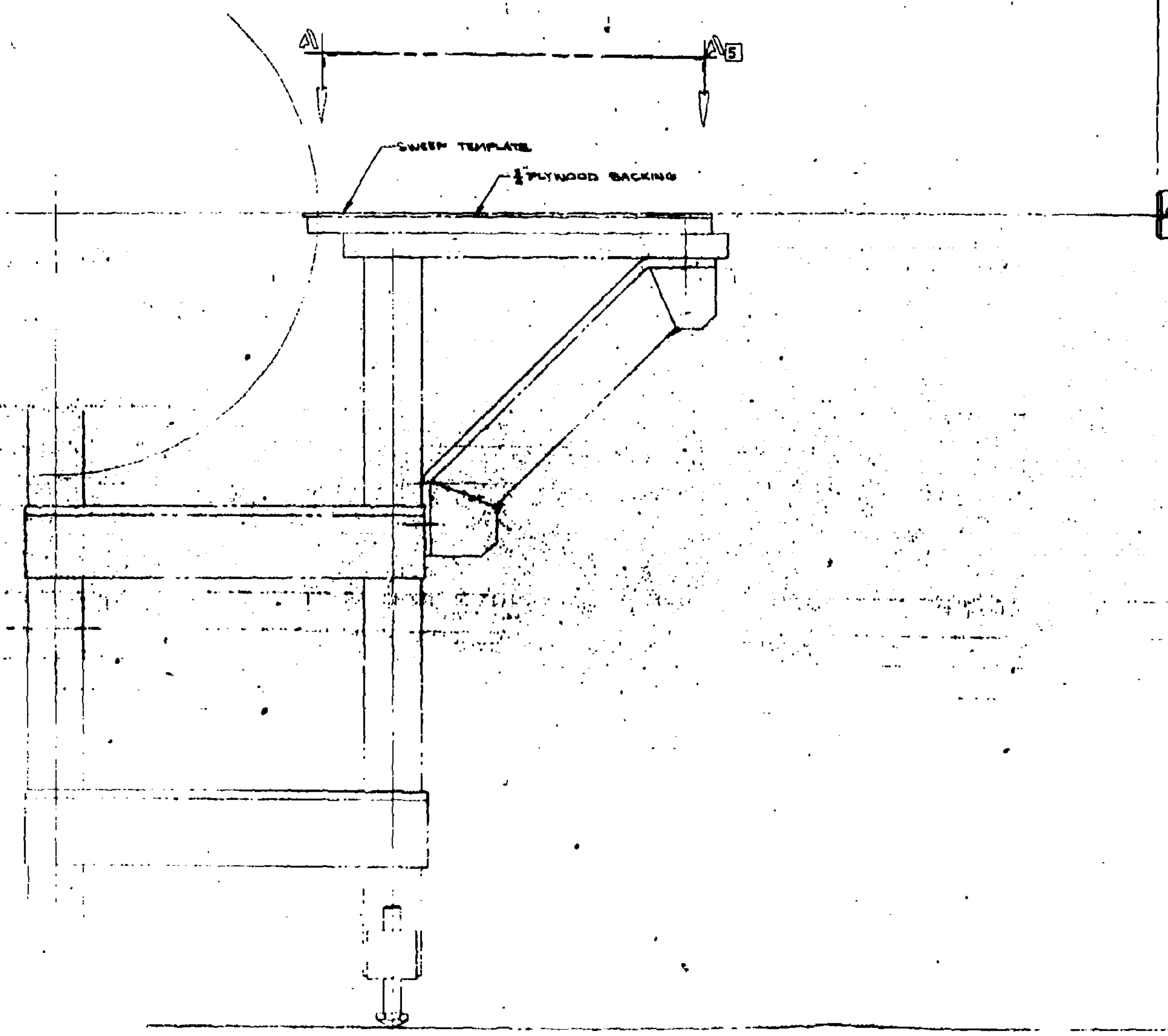
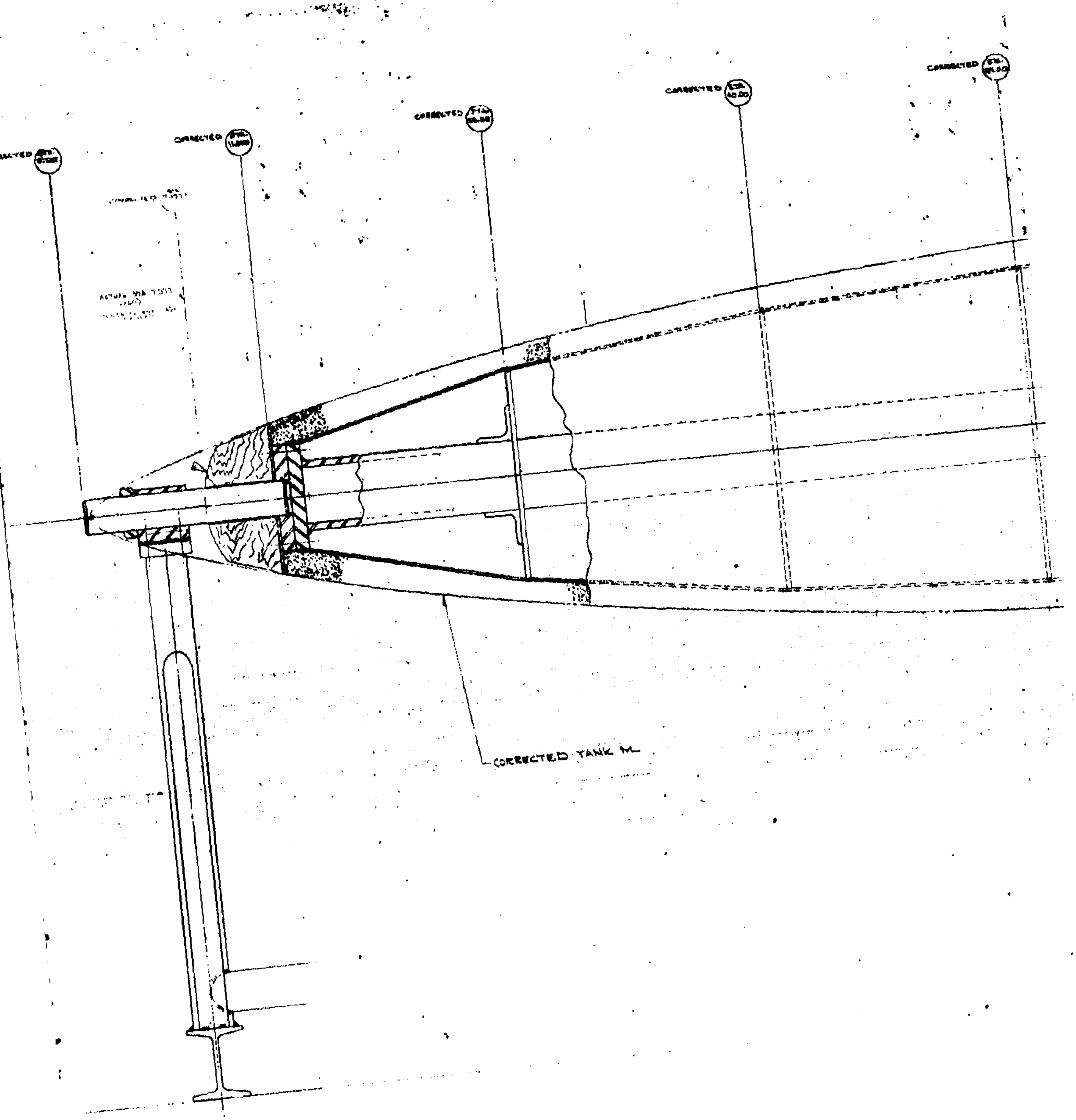


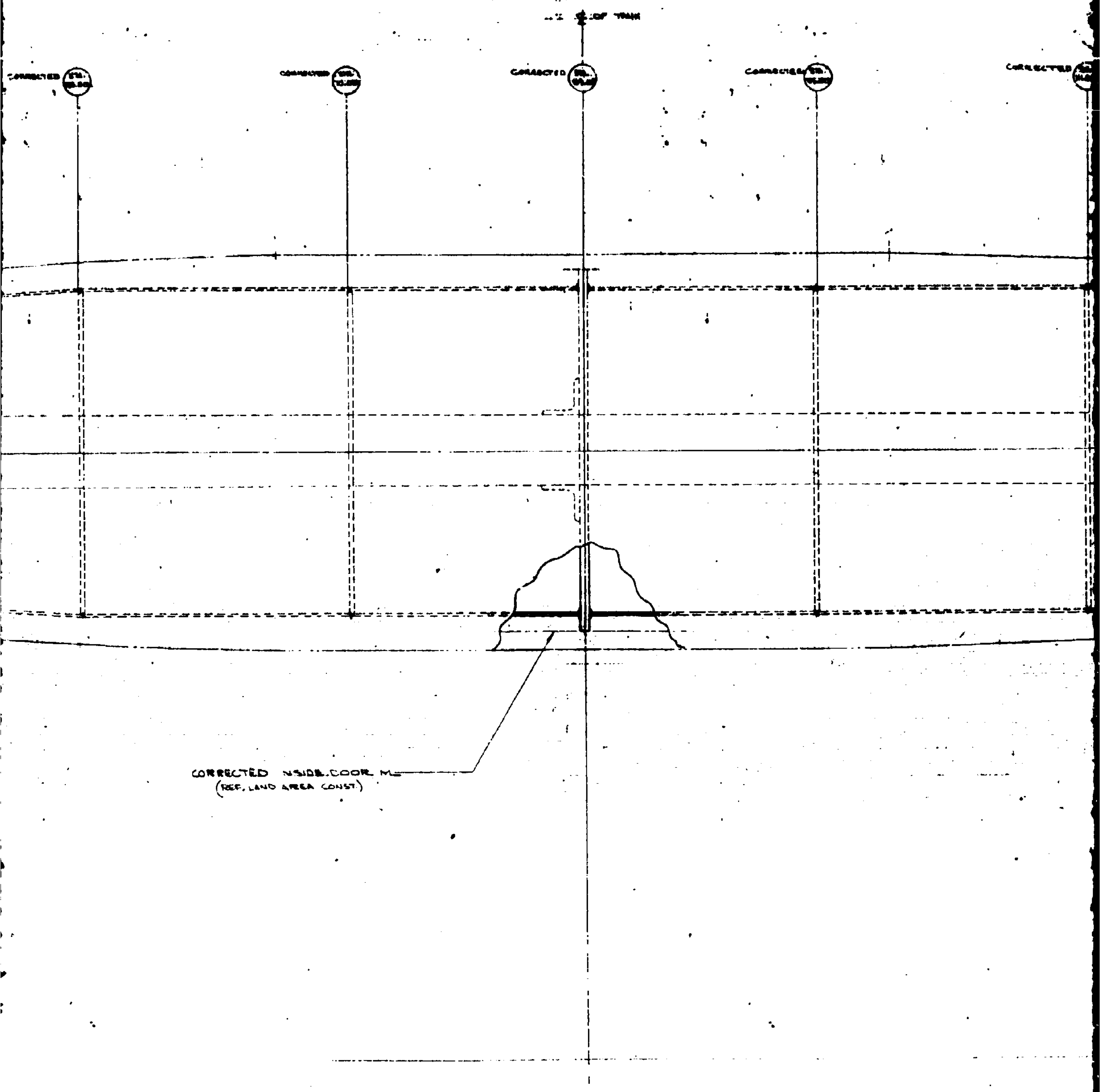
Figure 73 Bulkhead Installation Tool



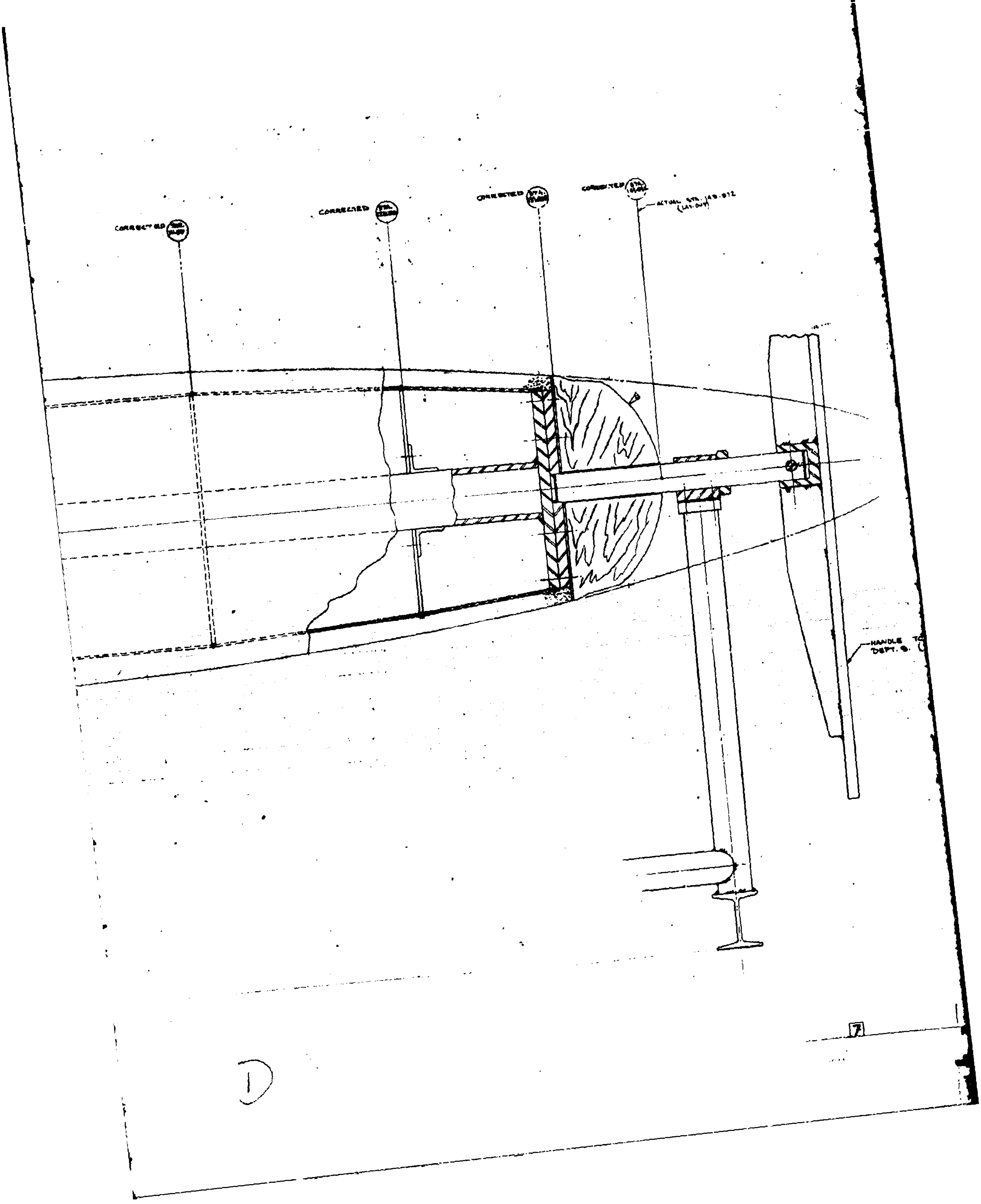
A TEMPLATE APPLICATION

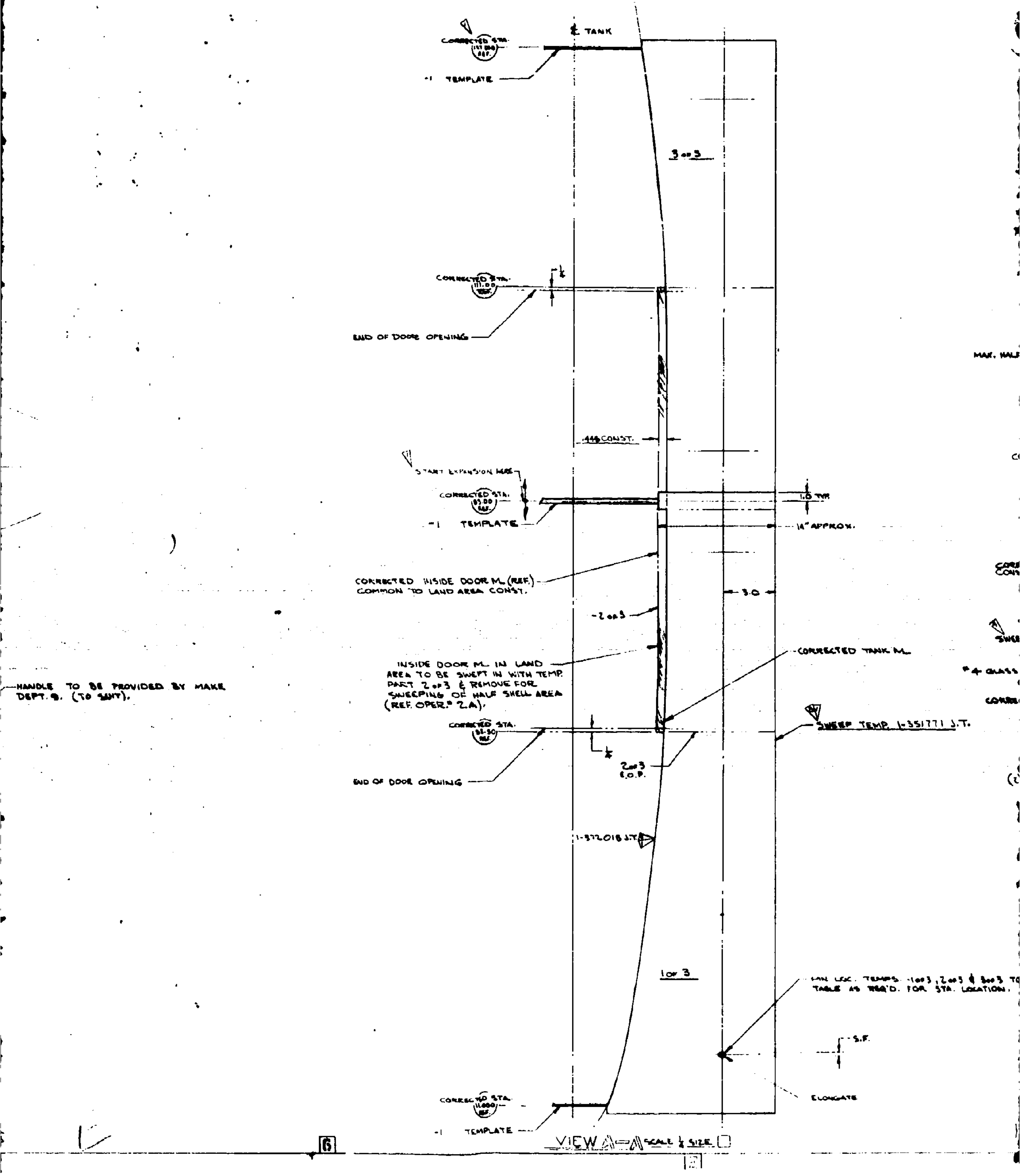


B

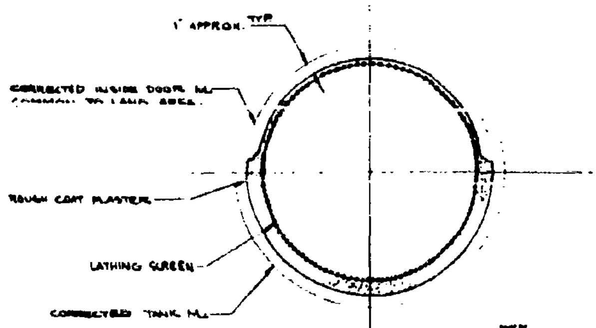

CORRECTED
CORRECTED
CORRECTED
CORRECTED
CORRECTED
CORRECTED NSIDE.COOR ML
(REF. LAND AREA CONST.)

C


CORRECTED
CORRECTED
CORRECTED
CORRECTED
HANDLE
DEPT.



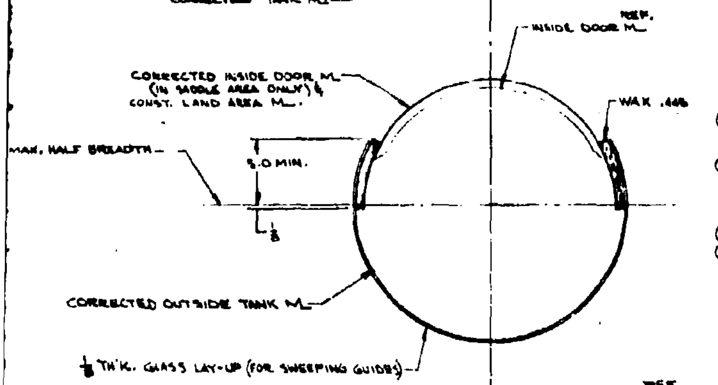
℄ TANK
CORRECTED STA. (117.00) REF.
-1 TEMPLATE
3 OF 3
CORRECTED STA. (111.00) REF.
END OF DOOR OPENING
.446 CONST.
START EXPANSION HERE
CORRECTED STA. (85.00) REF.
-1 TEMPLATE
1.0 TYP.
14" APPROX.
CORRECTED INSIDE DOOR M.L. (REF.) COMMON TO LAND AREA CONST.
3.0
-2 OF 3
INSIDE DOOR M.L. IN LAND AREA TO BE SWEPT IN WITH TEMP. PART 2 OF 3 & REMOVE FOR SWEEPING OF HALF SHELL AREA (REF. OPER.# 2.A).
CORRECTED TANK M.L.
HANDLE TO BE PROVIDED BY MAKE DEPT. 9. (TO SUIT).
CORRECTED STA. (55.30) REF.
SWEEP TEMP. 1-351771 J.T.
END OF DOOR OPENING
2 OF 3 E.O.P.
1-372016 J.T.
1 OF 3
S.F.
ELONGATE
CORRECTED STA. (11.000) REF.
-1 TEMPLATE
VIEW A-A SCALE 1/2 SIZE
6



OPER. #1

(A) ROUGH COAT PLASTER TO WITHIN APPROX. 1" INSIDE TANK & INSIDE DOOR M.L. ENTIRE TOOL.

(B) FINISH PLASTER COAT EXCEPT FROM STA. 52.60 TO STA. 111 ON SADDLE DOOR AREA.



OPER. #2

(A) FINISH PLASTER HALF SHELL AREA (OPPOSITE SADDLE DOOR SIDE) TO 1/8 FROM MAX. HALF BREADTH & TO INSIDE DOOR CORRECTED M.L. (LAND AREA M.L. CONST. REF. .446 DIM.).

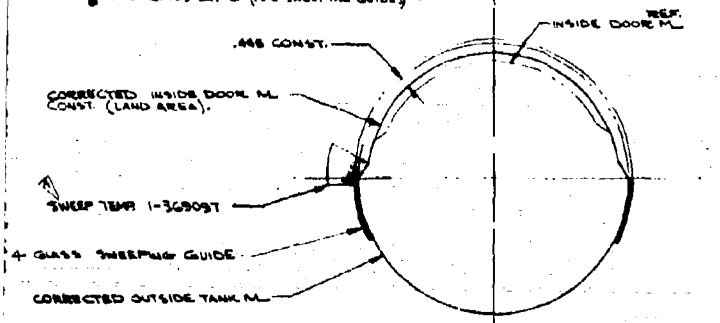
(B) WAX 5.0 MIN. PAST MAX. HALF BREADTH TO FINISHED HALF SHELL HEIGHT (OUTSIDE TANK M.L.).

(C) ADD SADDLE DOOR PERIPHERY LINES TO PLASTER & WAX REF MAX. HALF BREADTH (CONST. TO OUTSIDE PERIPHERY OF SADDLE DOOR. (FOR OUT-LINE OF CUT-OUT IN GLASS SWEEPING GUIDE).

(D) LAY-UP (4) GLASS 1/8 THK. SWEEPING GUIDES.

(E) CUT-OUT GLASS SWEEPING GUIDE #4 (REF. LAY-OUT LINES FROM PLASTER & WAX).

NOTE: SWEEPING GUIDES #1, #2 & #3 USED FOR FABRICATION OF HSK-575.

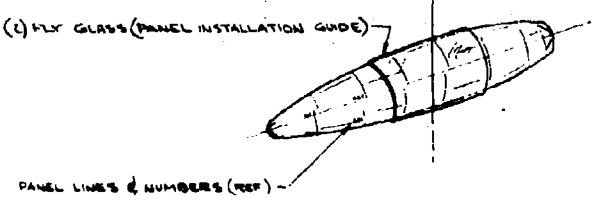


OPER. #3

(A) SWEEP IN TAPER AREA AROUND SADDLE DOOR USING GLASS SWEEPING GUIDE & SWEEP TEMP. 1-369097 J.T.

OPER. #4

(A) CONSTRUCT FEMALE TOOL HSK-577



OPER. #5

(A) ADD PANEL LAY-UP OUT-LINE & NUMBERS TO MODEL.

OPER. #6

(A) LAY-UP (2) PLY GLASS PANEL INSTALLATION GUIDES. (HSK-198)

(B) LAY-OUT & NUMBER GUIDES.

1- ALL STATIONS EXPANDED BY 1

& 3 TO LOCATION.

SEQUENCE OF OPERATIONS FOR SADDLE DOOR AREA & TOOL FUNCTIONS SCALE 1/4 SIZE APPROX.
(SHOWN AT CORRECTED TANK STA. 82.00)

1-372018 J.T.
1-369099 J.T.
1-369098 J.T.
1-551771 J.T.
1-369097 J.T.

C/D INFO.

3

2

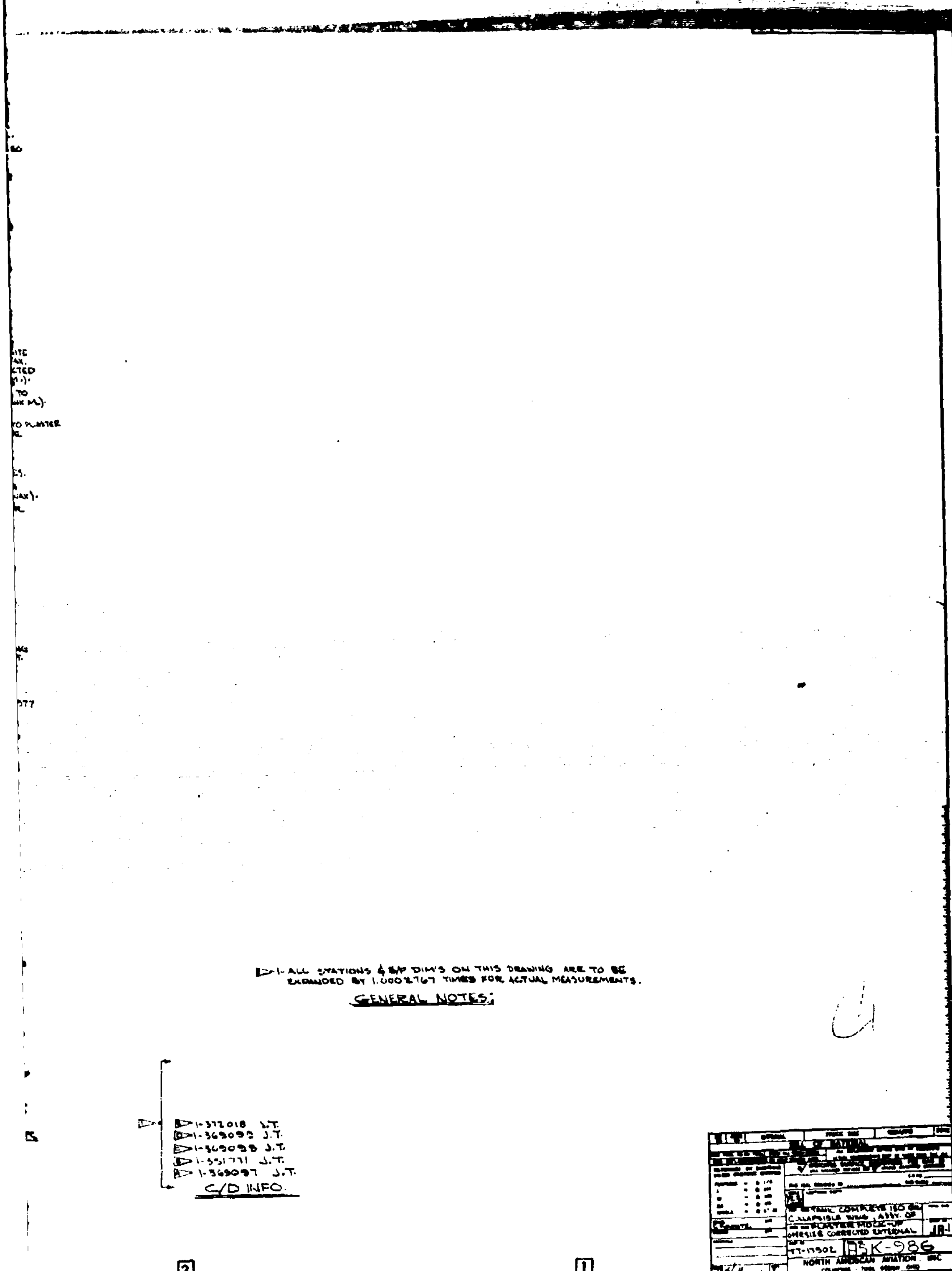
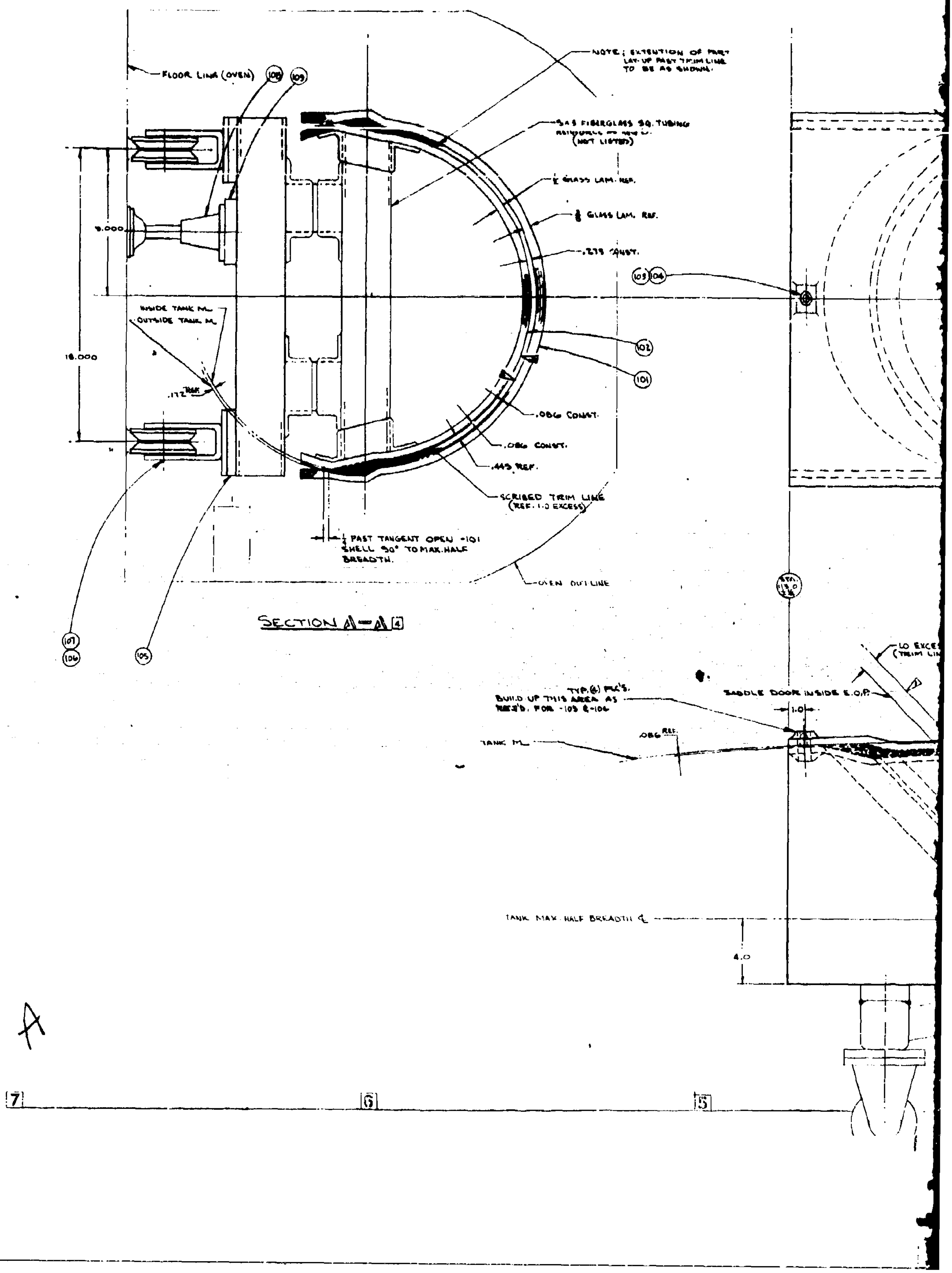
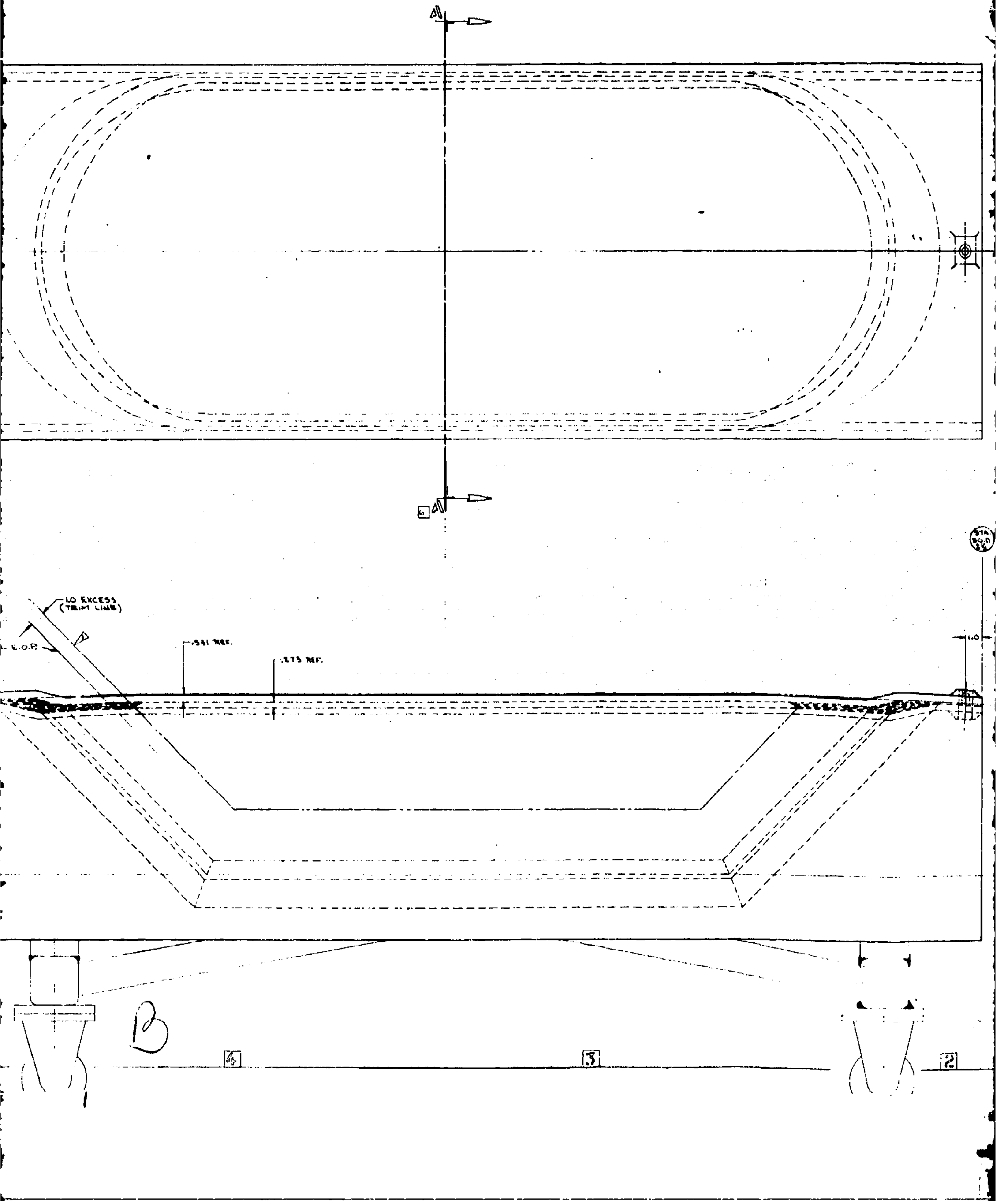


Figure 74 External Male Plaster Mandrel



FLOOR LINE (OVEN)
108
109
NOTE; EXTENTION OF PART LAY-UP PAST TRIM LINE TO BE AS SHOWN.
(NOT LISTED)
GLASS LAM. REF.
GLASS LAM. REF.
.275 CONST.
103
104
9.000
18.000
INSIDE TANK M.L.
OUTSIDE TANK M.L.
.172
102
101
.086 CONST.
.086 CONST.
.445 REF.
SCRIBED TRIM LINE
(REF. 1.0 EXCESS)
PAST TANGENT OPEN -101 SHELL 90° TO MAX. HALF BREADTH.
OVEN OUTLINE
SECTION A-A 4
107
106
105
TYP.(4) PLC'S.
BUILD UP THIS AREA AS REQ'D. FOR -103 & -106
SADDLE DOOR INSIDE E.O.P.
1.0
.086 REF.
TANK M.L.
TANK MAX. HALF BREADTH ℄
4.0
A
7
6
5



A
A
1.0 EXCESS
(TRIM LINE)
.541 REF.
.275 REF.
1.0
B
4
3
2

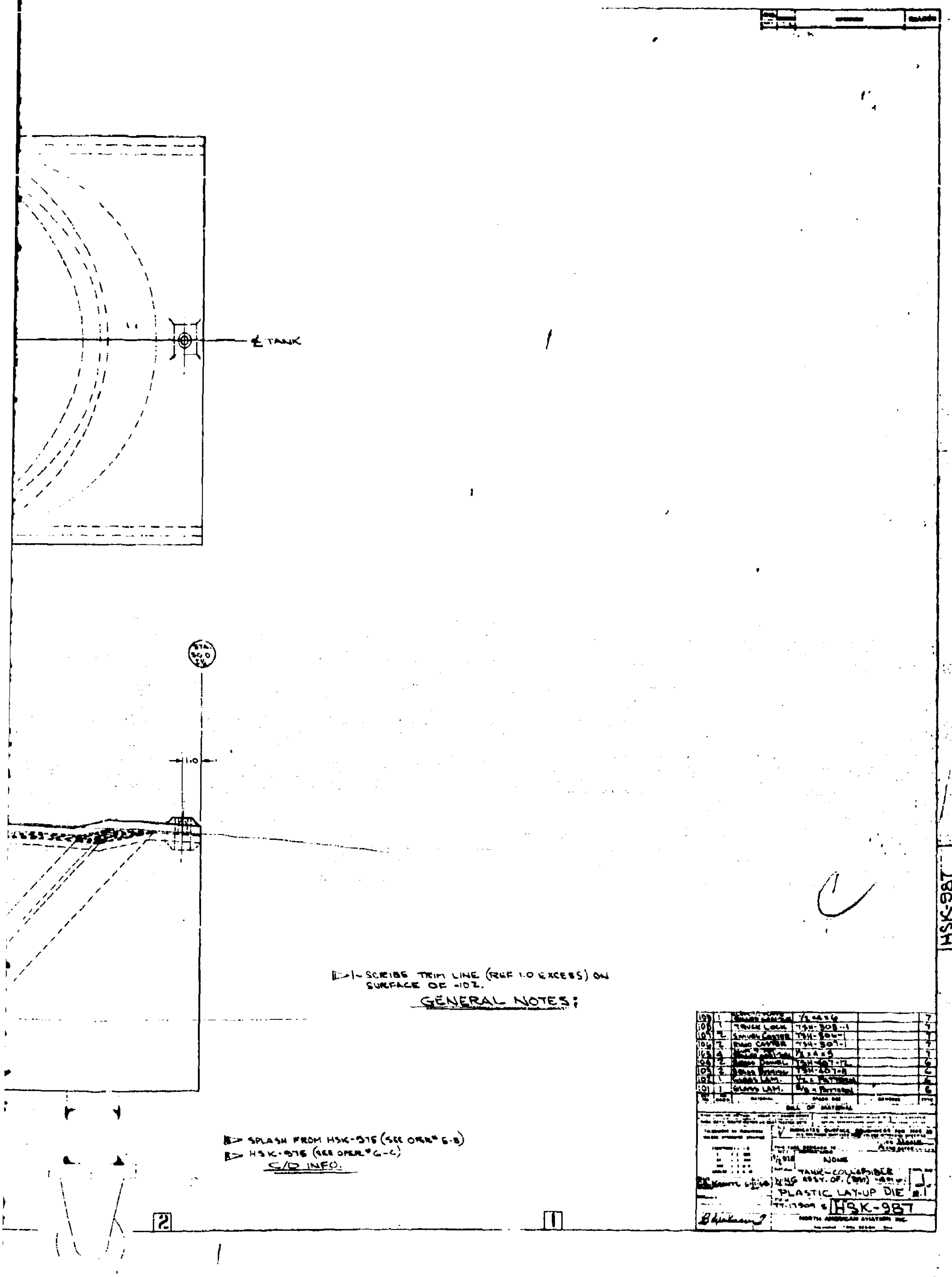


Figure 75 Hardback Lay-up Die

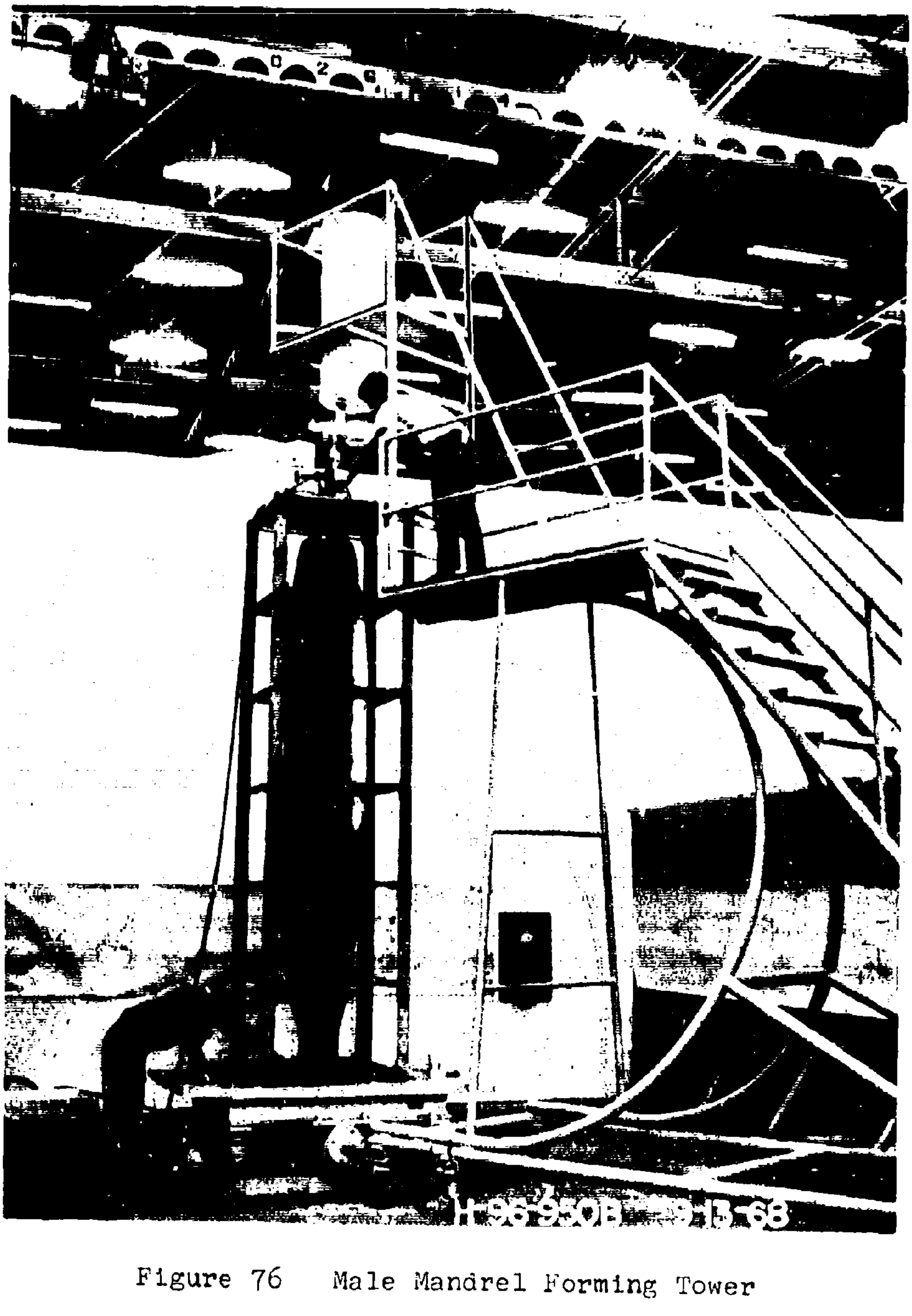


Figure 76   Male Mandrel Forming Tower

Figure 77 Silicone Bag Male Mandrel

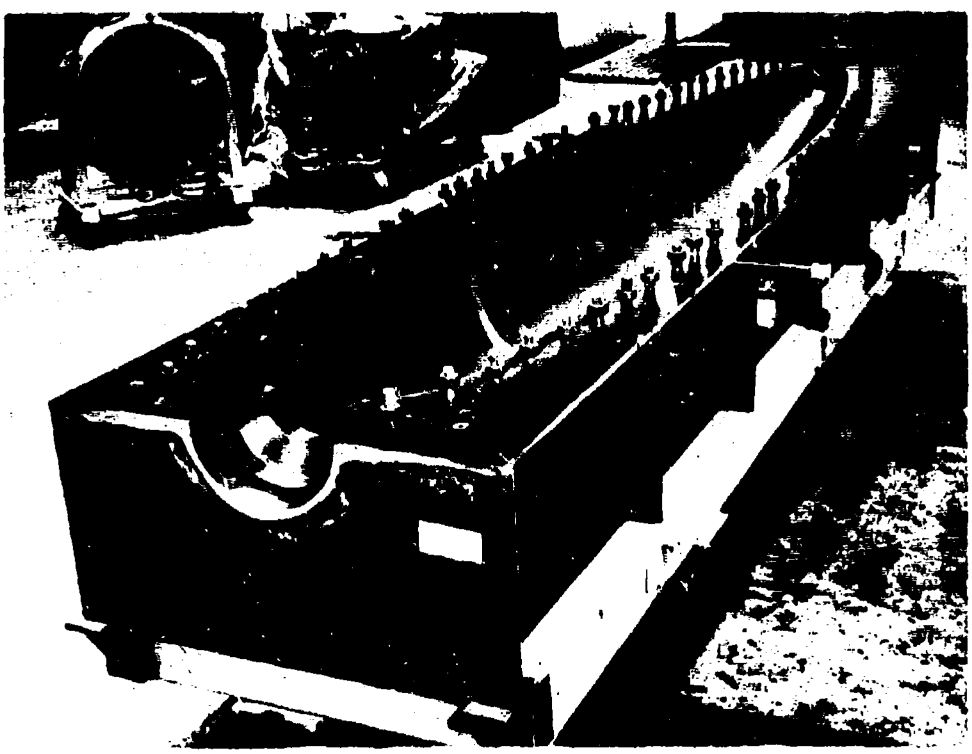


Figure 78 Top Half of Final Female Curing Tool

Figure 79 Bottom Half of Final Female Curing Tool

Figure 80 Bolting Ring and Pan Turned Tools

Figure 81 Hardback Tool

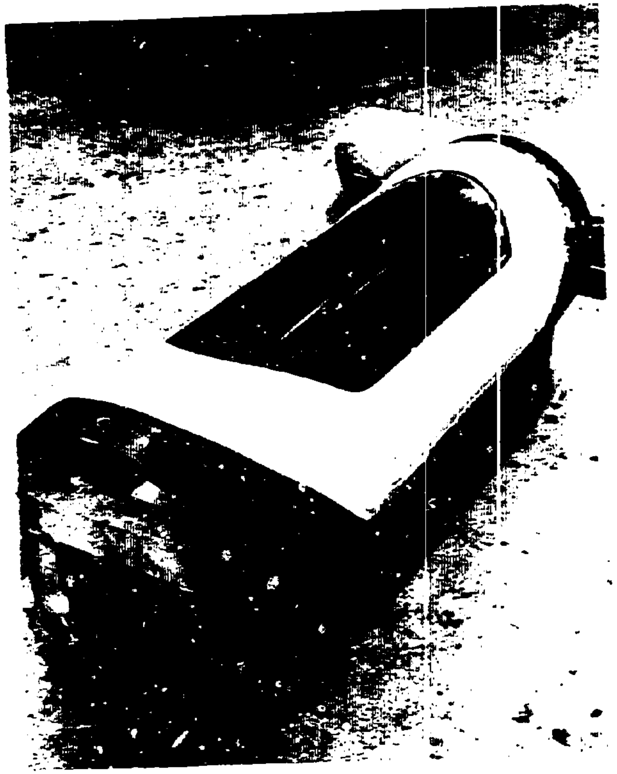


Figure 82 Land Area Tool and Partial Lay-up

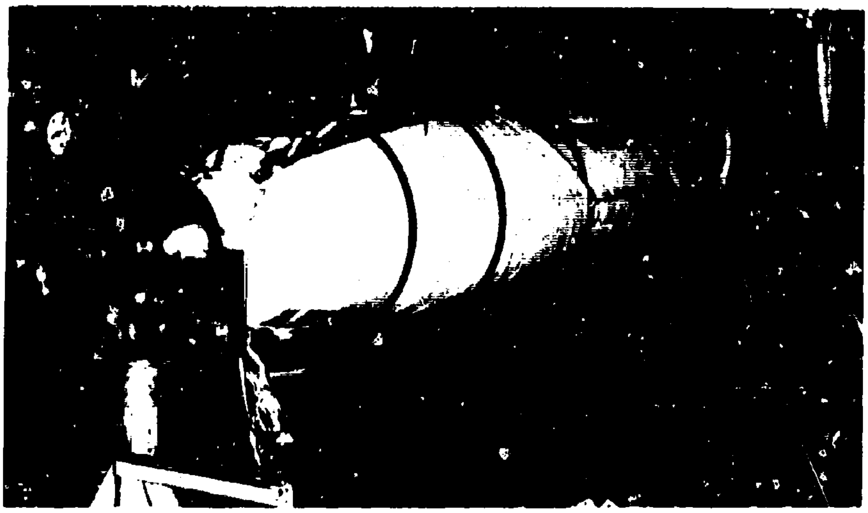


Figure 83 Final Vacuum Bagging For Compaction

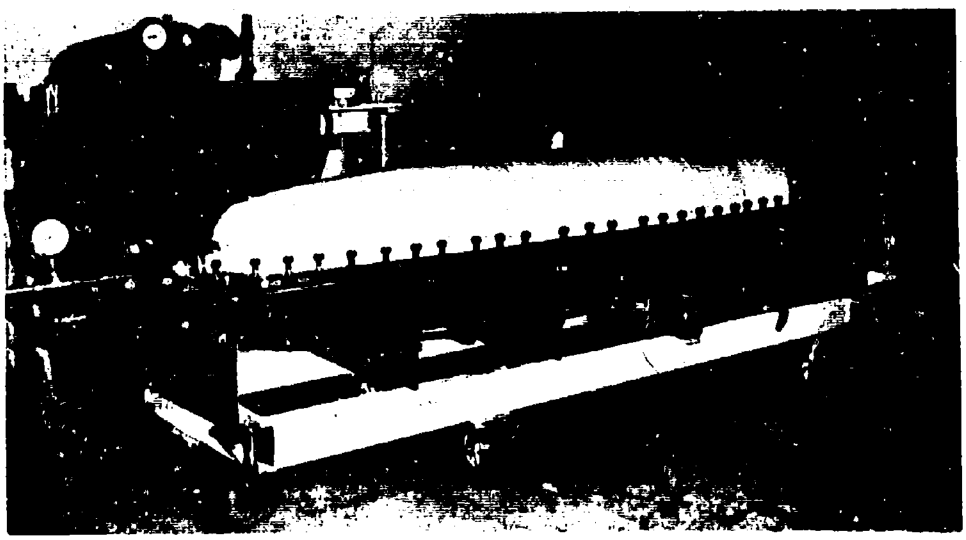


Figure 84 Wet Lay-up Tank in Female Tool

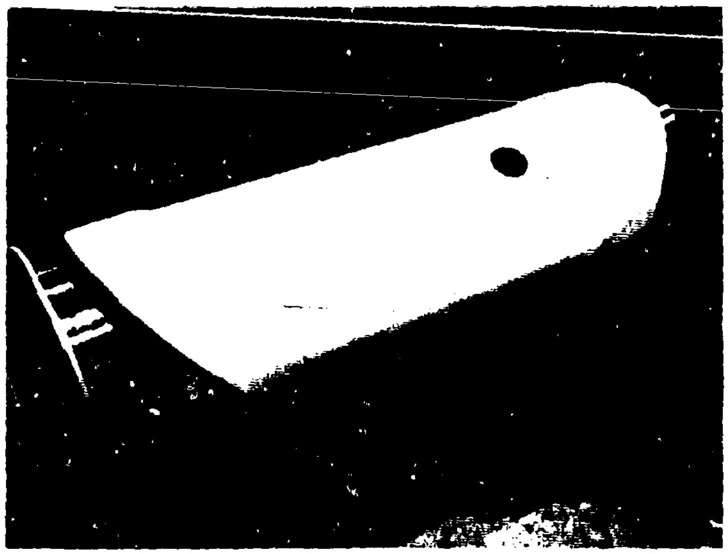


Figure 85 Hardback Tool and Bottom Skin Lay-up

Figure 86 B-Staged and Zone Cured Tank

Figure 87 Tank Folded Centrally

Figure 88 Bottom View of Folded Tank

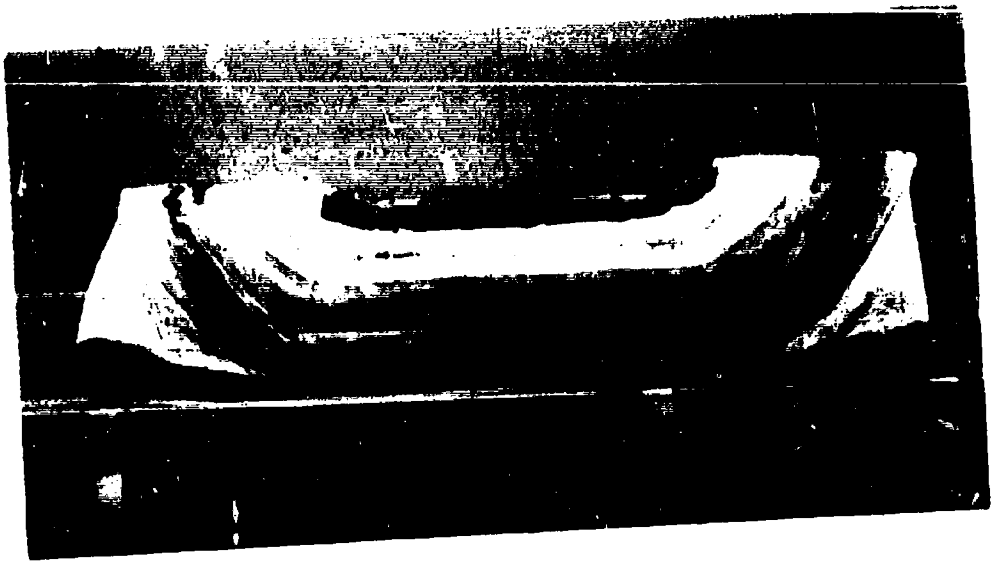


Figure 89 Partial Collapsed Tank

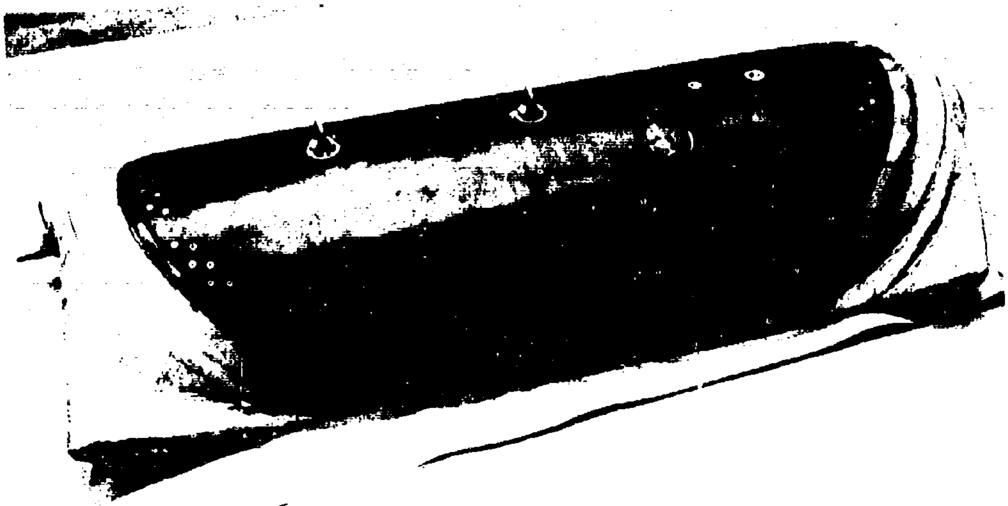
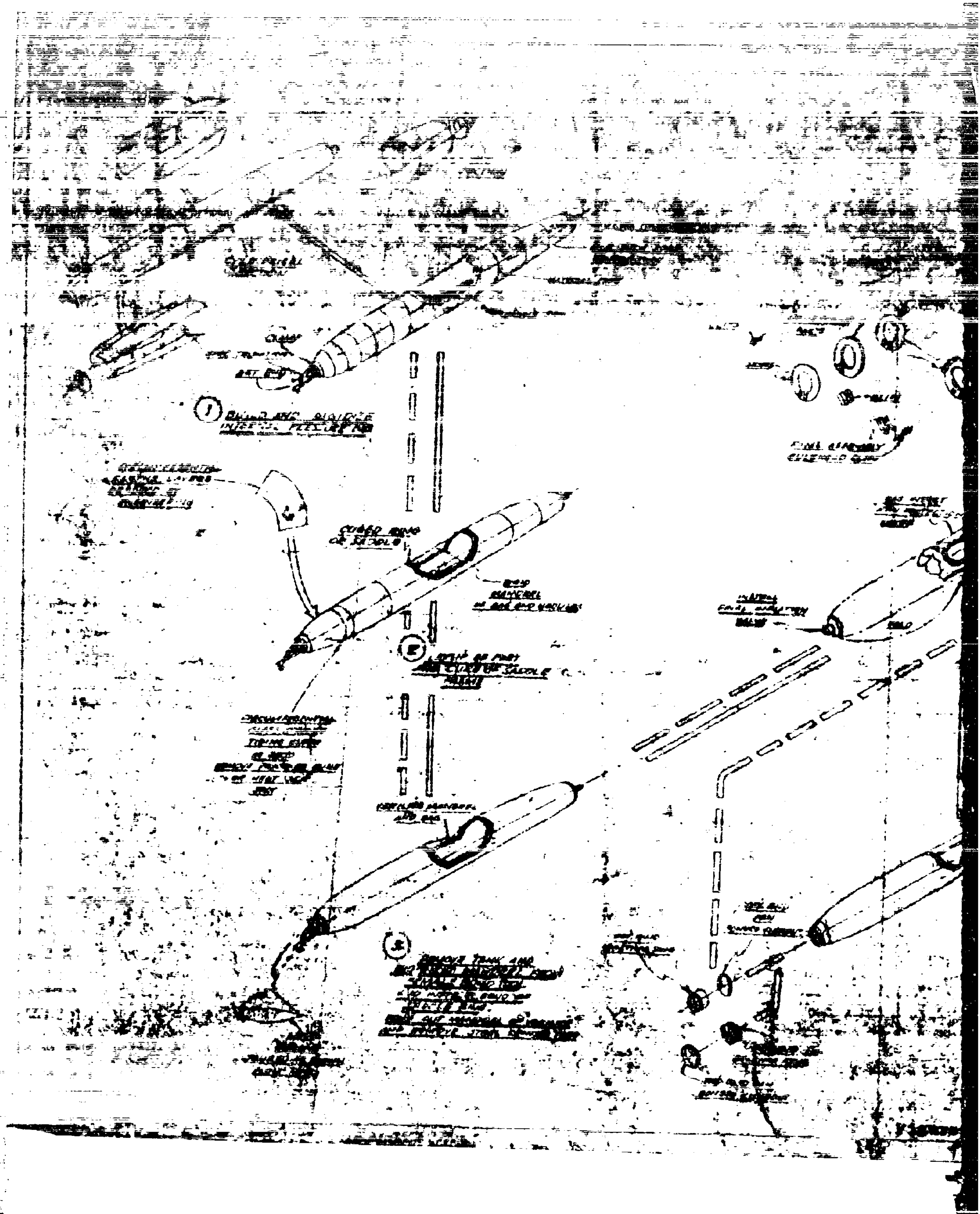


Figure 90 Complete Collapsed Tank



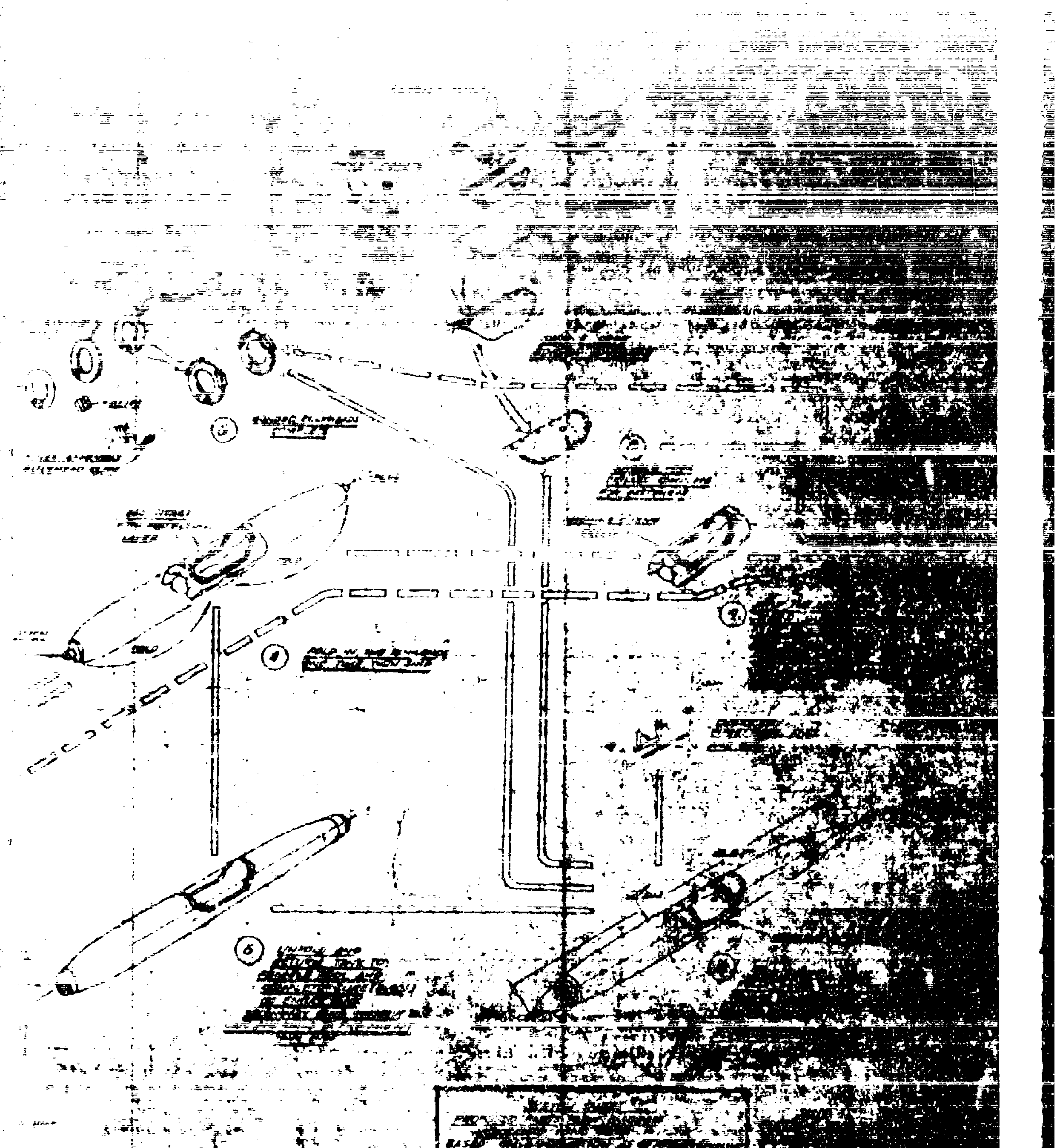


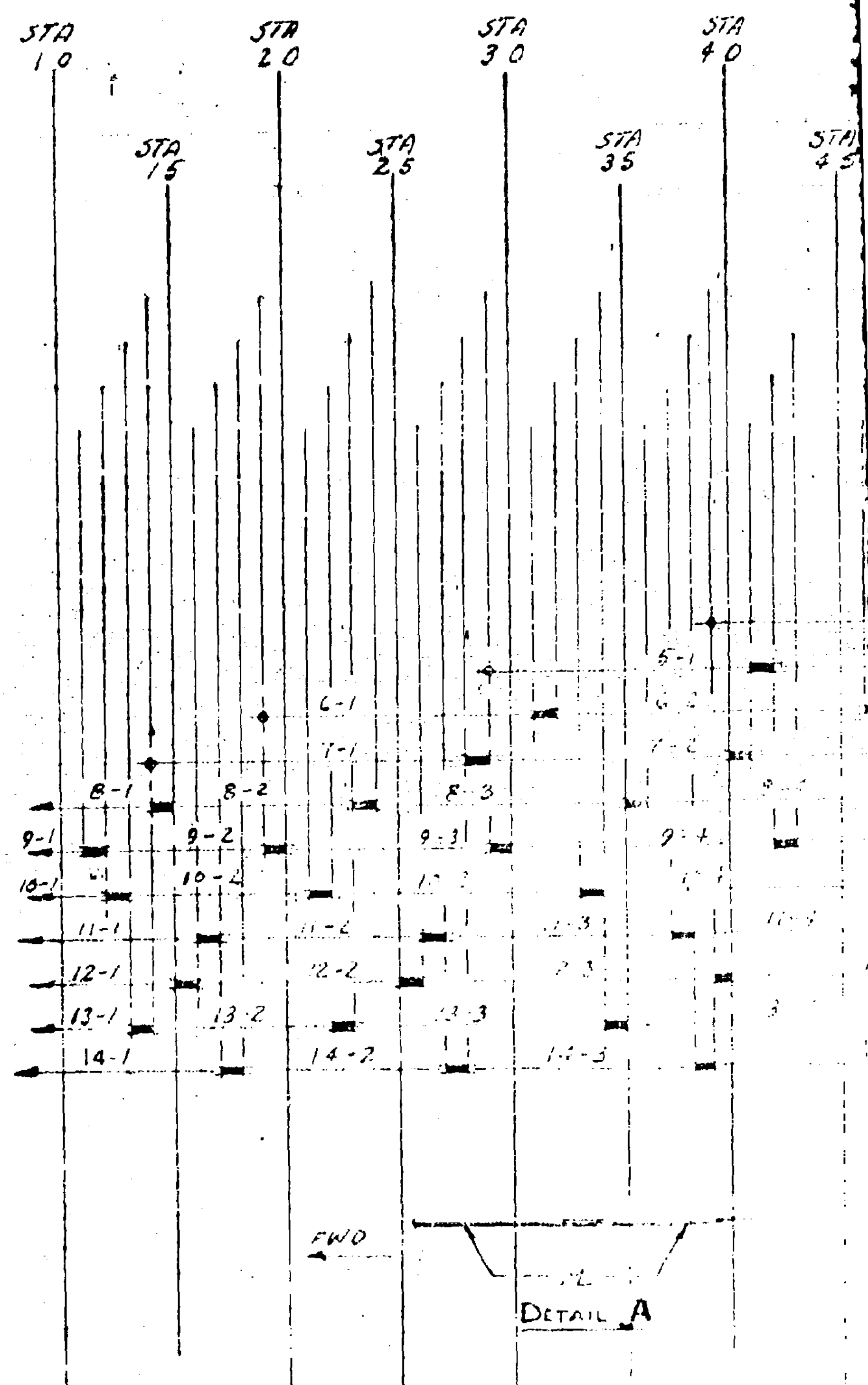
Figure 81 Parts Flow Diagram

1-1	STA 64-102
2-1	STA 64-102
3-1	STA 62-83.5
3-2	STA 82.5-114
4-1	STA 39-57
4-2	STA 53-69
4-3	STA 68-98
4-4	STA 97-113
4-5	STA 112-127
5-1	STA 29-42
5-2	STA 41-57
5-3	STA 56-72
5-4	STA 71-95
5-5	STA 94-110
5-6	STA 109-125
5-7	STA 124-137
6-1	STA 19-32
6-2	STA 31-47
6-3	STA 46-62
6-4	STA 61-82
6-5	STA 81-105
6-6	STA 104-120
6-7	STA 119-135
6-8	STA 134-END
7-1	STA 14-29
7-2	STA 28-41
7-3	STA 40-55
7-4	STA 54-70
7-5	STA 69-97
7-6	STA 96-112
7-7	STA 111-126
7-8	STA 125-138
7-9	STA 137-END
8-1	STA END TO 15
8-2	STA 14-24
8-3	STA 23-36
8-4	STA 35-48
8-5	STA 47-63
8-6	STA 62-83
8-7	STA 82-104
8-8	STA 103-119
8-9	STA 118-131
8-10	STA 130 TO END

9-1	FRONT TO 12
9-2	STA 11-20
9-3	STA 19-30
9-4	STA 29-43
9-5	STA 42-56
9-6	STA 55-71
9-7	STA 70-96
9-8	STA 95-111
9-9	STA 110-124
9-10	STA 123-137
9-11	STA 136 TO END

10-1	FRONT TO 13
10-2	STA 12-22
10-3	STA 21-34
10-4	STA 33-49
10-5	STA 48-64
10-6	STA 63-85
10-7	STA 84-103
10-8	STA 102-118
10-9	STA 117-133
10-10	STA 132 TO END

11-1	F
11-2	ST
11-3	ST
11-4	S
11-5	S
11-6	S
11-7	S
11-8	S
11-9	ST



PART NO'S. 6-8, 7-9, 8-10, 9-11, 10-10 & 11-9 STOP AT STA 140.12

PART NO'S 8-1, 9-1, 10-1, 11-1 & 12-1 STOP AT STA 8.13

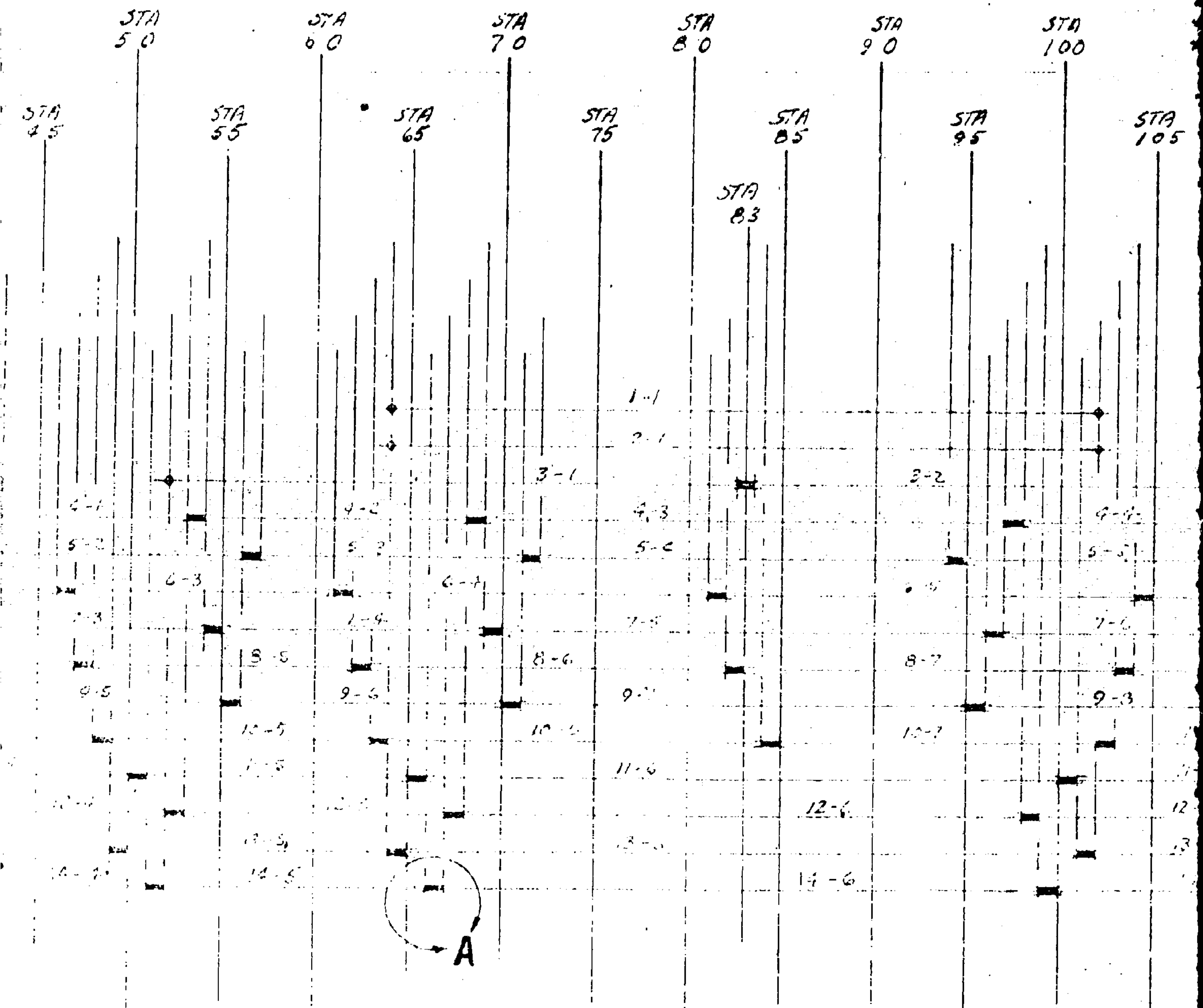
PREPARE PART NO'S 13-1, 14-1, 12-9, 13-9, 14-9 FROM CIRCULAR GORES TO FIT ENDS

ONE EACH PARTS 1-1 & 1-2 REQD

ADD 8" TO THE WIDTH OF PARTS 1-1 & 1-2

A

FRONT TO 17	12-1	FRONT TO 16	13-1	FRONT TO 14	14-1	FRONT TO 18
STA 16-27	12-2	STA 15-26	13-2	STA 13-23	14-2	STA 17-28
STA 26-38	12-3	STA 25-40	13-3	STA 22-35	14-3	STA 27-39
STA 37-51	12-4	STA 39-53	13-4	STA 34-50	14-4	STA 38-52
STA 50-66	12-5	STA 52-68	13-5	STA 49-65	14-5	STA 51-67
STA 65-101	12-6	STA 67-99	13-6	STA 64-102	14-6	STA 66-100
STA 100-116	12-7	STA 98-114	13-7	STA 101-117	14-7	STA 99-115
STA 115-129	12-8	STA 113-127	13-8	STA 116-132	14-8	STA 114-128
STA 128-TO END	12-9	STA 126-TO END	13-9	STA 131 TO END	14-9	STA 127-TO



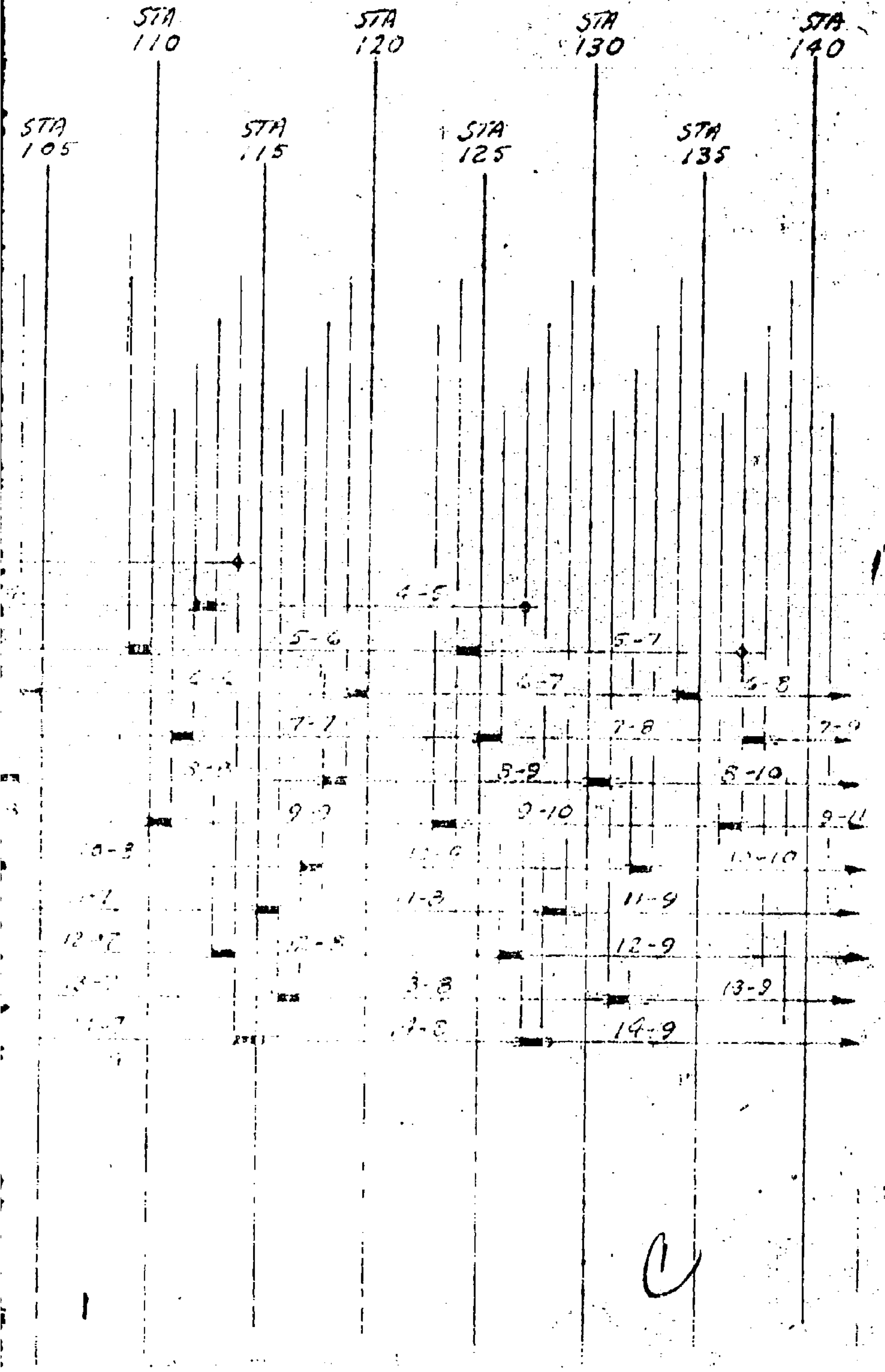
OVERLAP STATIONS PARALLEL
TO THE LONGITUDINAL AXIS OF THE TANK

EXPANDABLE RIGIDIZING EXTERNAL AIRCRAFT FUEL TANK

B

70 18
7 - 29
7 - 39
38 - 52
51 - 67
66 - 100
99 - 115
14 - 128
127 - TO END

(Identical Parts (Typ))



$S = 2\frac{3}{8}$" Min. Space For Circumf. Laps in Cylindrical Sections

$S = 1\frac{11}{16}$" Min. Space For Circumf. Laps in Conical Sections

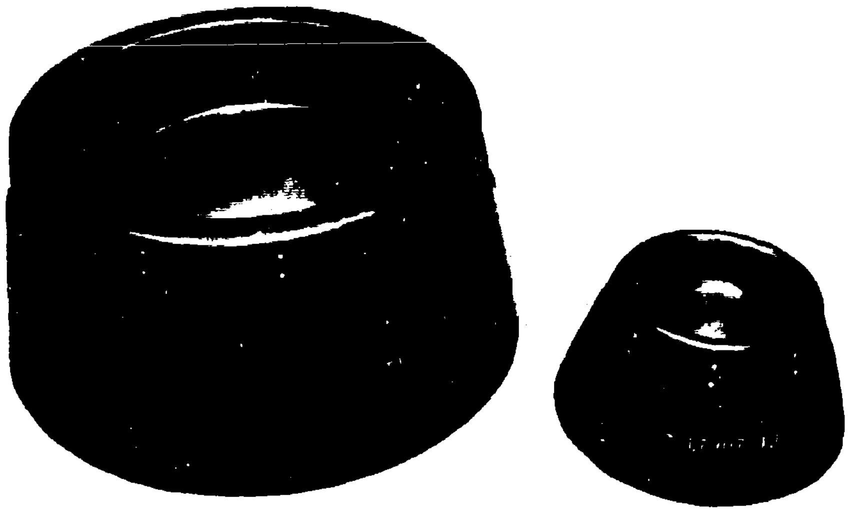


Figure 93 Outside View of Bolting Ring and Pan

Figure 94 Inside View of Bolting Ring and Pan

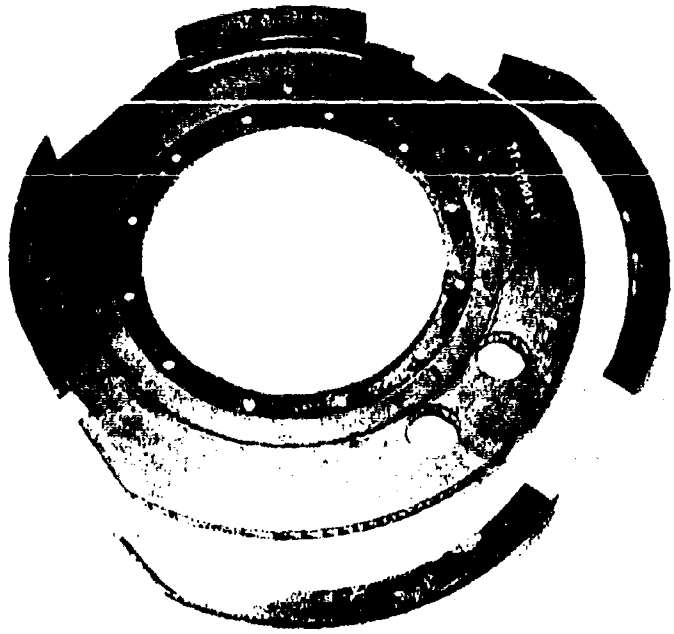


Figure 95 Cured Bulkhead, Slosh Baffle and Clips

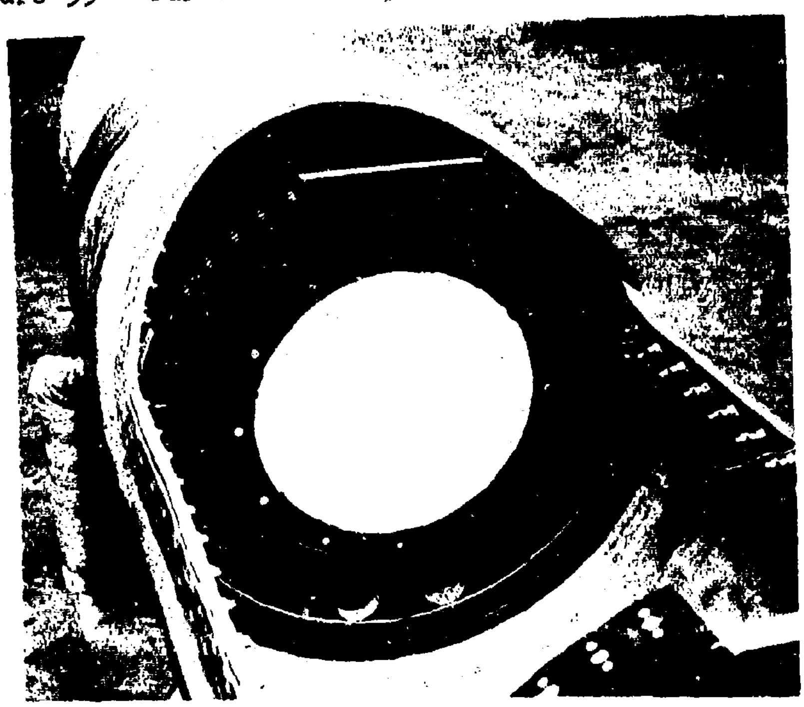


Figure 96 Installed Bulkhead and Slosh Baffle

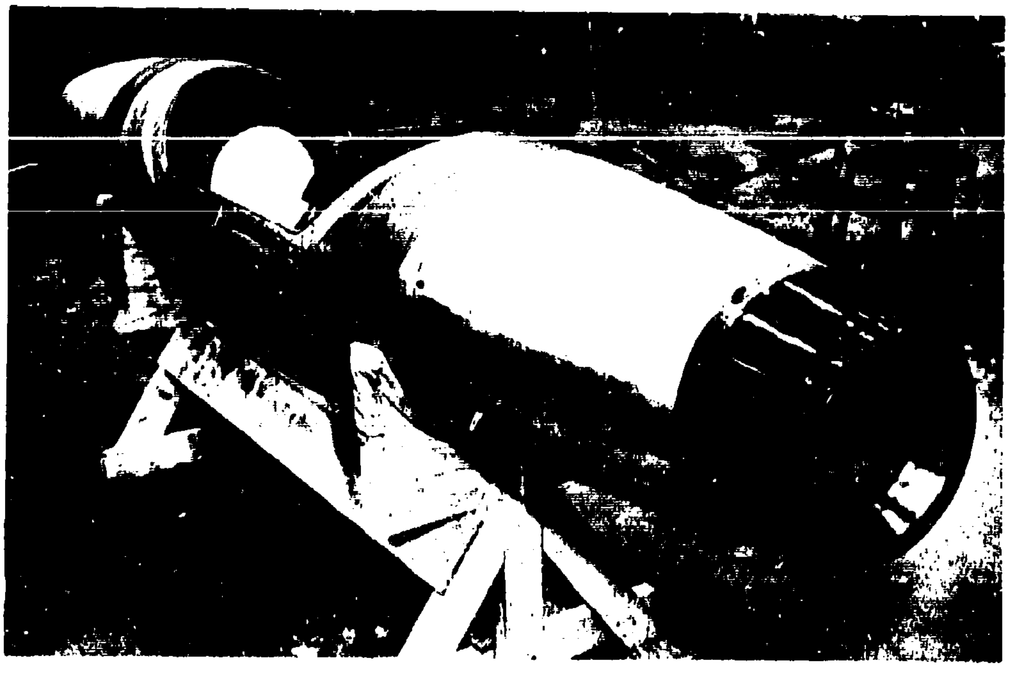


Figure 97 Rigidized Tank

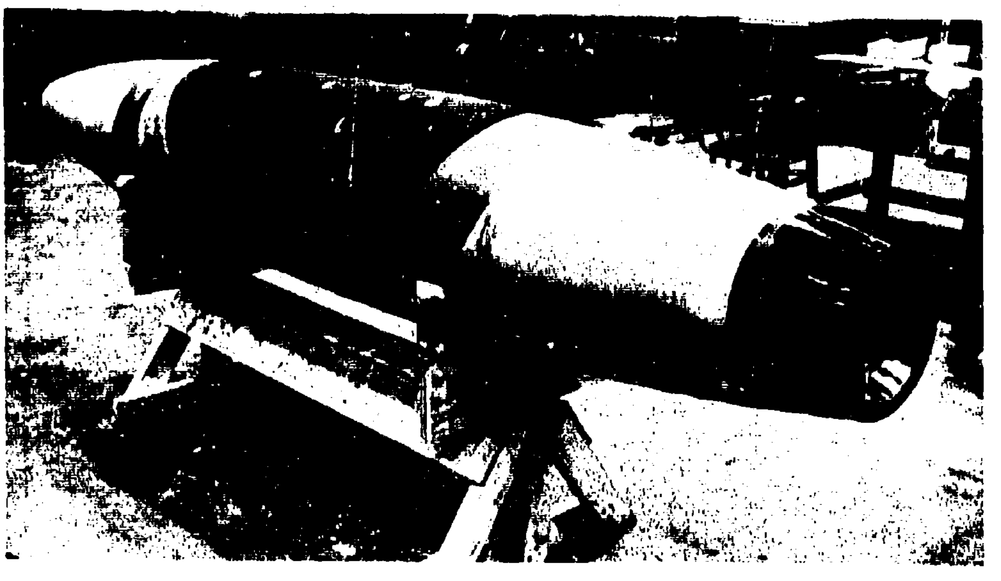


Figure 98 Rigidized Tank, Complete

APPENDIX II

TABLES

EXPANDABLE RIGIDIZABLE
EXTERNAL AIRCRAFT FUEL TANK

APPENDIX II
LIST OF TABLES

TABLE I
Page 1 of 13
[illegible] SYSTEM SCREENING TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
1	Epon 828 p-phenylenediamine	100 8.93	Tack free	Delaminated(1) Delaminated(2) OK-5" min.bend(3)	67.16(1)^{E} 81.73(2)^{E} 84.60(3)^{E}	(1)^{E} (2)^{E}	(1) (2)	23,940^{E} 21,2[illegible]^{E}	.89 x 10^{6E} .[illegible]3 x 10^{6E}
2	Epon 828 p-phenylenediamine	100 7.2							
3	Epon 828 N-methylaniline	100 35.6			Cancelled - Tests Indicate No Cure Possible				
4	Epon 828 N-methylaniline	100 28.5			Cancelled - Tests Indicate No Cure Possible				
5	Epon 828 Aniline	100 15.25			Cancelled - Tests Indicate No Cure Possible				
6	Epon 828 Aniline	100 12.2			Cancelled - Tests Indicate No Cure Possible				
7	Epon 828 Bisphenol-A B.D.M.A.	100 36.9 .62		Would not fold	25.9	52,000	3.2 x 10^{6}	79,517	3.5 x 10^{6}
8	Epon 828 Bisphenol-A B.D.M.A.	100 29.5 .5			Cancelled				
9	Epon 828 M.N.A. B.D.M.A.	100 56 .62		Would not fold	39.6	41,620	2.7 x 10^{6}	67,816	2.4 x 10^{6}
10	Epon 828 M.N.A. B.D.M.A.	100 45 .5		Would not fold	35.2	45,666	2.7 x 10^{6}	82,775^{A}	3.0 x 10^{6}
11	Blacar RS-31 Epon 828 Di Cy	100 3 100 4	Tack free	OK	30.0^{A}	29.772^{A}	1.8 x 10^{6A}	28,032^{A}	1.[illegible] x 10^{6A}
12	Blacar RS-31 Epon 828 Di Cy	100 3 200 8	Slightly tacky	OK	33.9^{A}	Blistered^{A}			
13	Blacar RS-31 Epon 828 Di Cy	100 3 250 10	Tacky	OK	38.5^{A} 38.02^{C}	25,600^{A} 33,700^{C}	1.6 x 10^{6A} 2.41 x 10^{6C}	37,265^{A} 26,300^{C}	1.5 x 10^{6A} 2.5 x 10^{6C}
14	Blacar RS-31 Epon 828 Di Cy	100 3 300 12	Tacky	OK, but surface on I.D. whitened	37.2^{A} 34.08^{C}	32,682^{A} 46,500^{C}	1.78 x 10^{6A} 2.56 x 10^{6C}	40,550^{A} 67,400	1.7 x 10^{6A} 2.[illegible] x 10^{6C}
15	Blacar RS-31 Epon 828 BF_3	100 3 100 3	Tack free	OK	27.6^{A}	20,000^{A}	1.5 x 10^{6A}	28,500^{A}	1.5 x 10^{6A}

TABLE I

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RESIN SYSTEM SCREENING TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
16	Blacar RS-31 Epon 828 BF_3	100 3 200 6	Slightly tacky	OK	33.2^A 30.50^C	17,800^A 39,300^C	1.5×10^{6A} 2.54×10^{6C}	21,505^A 51,000^C	1.1×10^{6A} 2.8×10^{6C}
17	Blacar RS-31 Epon 828 BF_3	100 3 250 7.5	Tacky	OK	34.3^A 29.47^C	27,179^A 41,500^C	1.79×10^{6A} 2.93×10^{6C}	32,612^A 63,000^C	1.6×10^{6A} 3.3×10^{6C}
18	Blacar RS-31 Epon 828 BF_3	100 3 300 9	Tacky	Delaminated	38.9^A 32.28^C	22,800^A ^{C}	1.6×10^{6A} ^{C}	10,980^A 86,144^C	0.8×10^{6A} 2.83×10^{6C}
19	Blacar RS-31 Santoset Benzoyl peroxide	100 3 100 8	Tack free	OK	43.5^A	8,960^A	$.42 \times 10^{6A}$	—^{A}	$.4 \times 10^{6A}$
20	Blacar RS-31 Santoset Benzoyl peroxide	100 3 200 16	Tack free	OK	45.9^A	23,000^A	1.52×10^{6A}	8,348^A	$.8 \times 10^{6A}$
21	Blacar RS-31 Santoset Benzoyl peroxide	100 3 250 20	Tack free	OK	39.3^A	24,900^A	1.49×10^{6A}	8,360^A	$.4 \times 10^{6A}$
22	Blacar RS-31 Santoset Benzoyl peroxide	100 3 300 24	Tack free	OK	45.0^A	24,800^A	1.55×10^{6A}	15,180^A	1.08×10^{6A}
23	Butvar Epon 828 Di Cy	100 100 4	Tacky, sticks to itself	OK	49.6^A	14,500^A 24,700^D	1.00×10^{6A} 1.24×10^{6D}	12,170^A	$.4 \times 10^{6A}$
24	Butvar Epon 828 Di Cy	100 200 8	Tacky, sticks to itself	OK	42.1^A	20,400^A 35,100^D	1.6×10^{6A} 1.76×10^{6D}	40,415^A 41,000^D	1.6×10^{6A} 1.54×10^{6C}
25	Butvar Epon 828 Di Cy	100 250 10	Tacky, sticks to itself	OK, but whitened in I.D.	40.2^A 30.82^C	32,300^A 35,500^D 43,000^C	2.13×10^{6A} 1.93×10^{6D} 2.96×10^{6C}	42,714^A 44,780^D 66,200^C	1.4×10^{6A} 1.56×10^{6C} 2.6×10^{6C}
26	Butvar Epon 828 Di Cy	100 300 12	Tacky, sticks to itself	OK, but whitened in I.D.	45.0^A 34.67^C	32,900^A 42,100^D 44,000^C	2.34×10^{6A} 2.11×10^{6D} 2.8×10^{6C}	40,436^A 51,400^D 58,500^C	1.6×10^{6A} 1.95×10^{6D} 2.7×10^{6C}
27	Butvar Epon 828 BF_3	100 100 3	Tacky, sticks to itself	OK	49.1^A	12,500^A 30,700^D	$.89 \times 10^{6A}$ 1.54×10^{6D}	21,073^A 25,200^D	0.8×10^{6A} $.95 \times 10^{6D}$

TABLE I

RESIN SYSTEM SCREENING TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
28	Butvar Epon 828 BF_3	100 200 6	Tacky, sticks to itself	OK, but whitened in I.D.	47.4^A	$13,320^A$ $33,600^D$	1.06×10^{6A} 1.63×10^{6D}	$26,344^A$ $23,000^D$	1.2×10^6 1.07×10^6
29	Butvar Epon 828 BF_3	100 250 7.5	Tacky, sticks to itself	OK, but whitened in I.D.	31.4^A 23.83^C	$19,150^A$ $28,300^D$ $24,150^C$	1.29×10^{6A} 1.42×10^{6D} 2.73×10^{6C}	$24,276^A$ $33,300^D$ $52,000^C$	1.3×10^6 1.54×10^6 3.0×10^6
30	Butvar Epon 828 BF_3	100 300 9	Tacky, sticks to itself	OK, but whitened in I.D.	44.8^A 30.55^C	$22,600^A$ $43,500^D$ $24,800^C$	2.00×10^{6A} 2.18×10^{6D} 3.02×10^{6C}	$28,140^A$ $43,700^D$ $56,000^C$	1.4×10^6 1.96×10^6 3.00×10^6
31	Butvar ERL 2256 BF_3	100 100 3	Tacky, sticks to itself	OK, but whitened in I.D.	43.35^A	$12,300^A$	1.11×10^{6A}	$5,780^A$	$.14 \times 10^6$
32	Butvar ERL 2256 BF_3	100 200 6	Tacky, sticks to itself	OK, but whitened in I.D.	40.19^A	$18,600^A$	1.49×10^{6A}	$19,700^A$	$.72 \times 10^6$
33	Butvar ERL 2256 BF_3	100 250 7.5	Tacky, sticks to itself	OK, but whitened in I.D.	34.83^A 33.17^C	$21,500^A$ $35,200^C$	1.70×10^{6A} 2.57×10^{6C}	$24,700^A$ $47,000^C$	1.21×10^6 2.6×10^6
34	Butvar ERL 2256 BF_3	100 300 9	Tacky, sticks to itself	OK, but whitened in I.D.	34.52^A 29.79^C	$23,100^A$ $39,000^C$	2.10×10^{6A} 2.96×10^{6C}	$36,000^A$ $58,000^C$	1.55×10^6 2.9×10^6
35	Butvar ERL 2256 Di Cy	100 150 4	Tacky, sticks to itself	OK, but whitened in I.D.	35.76^A	$18,900^A$	1.22×10^{6A}	$5,610^A$	$.37 \times 10^6$
36	Butvar ERL 2256 Di Cy	100 200 8	Tacky, sticks to itself	OK, but whitened in I.D.	31.76^A	$23,600^A$	2.04×10^{6A}	$13,600^A$	$.81 \times 10^6$
37	Butvar ERL 2256 Di Cy	100 250 10	Tacky, sticks to itself	OK, but whitened in I.D.	25.35^A 29.08^C	$21,400^A$ $34,500^C$	1.67×10^{6A} 2.08×10^{6C}	$15,900^A$ $28,500^C$	1.32×10^6 2.3×10^6
38	Butvar ERL 2256 Di Cy	100 300 12	Tacky, sticks to	OK, but whitened	28.37^A 27.21^C	$14,400^A$ $33,000^C$	1.50×10^{6A} 2.55×10^{6C}	$14,000^A$ $20,800^C$	1.32×10^6 2.0×10^6
[illegible]	Butvar PS-31 Epon 828 Di Cy	100 3 100 4	Tack free	OK	[illegible]	[illegible]	[illegible]	[illegible]	--
[illegible]	Butvar PS-31 Epon 828 Di Cy	100 3 200 8	Tacky	OK	[illegible]	[illegible]	[illegible]	$53,700^A$	1.27×10^6
41	Butvar PS-31 Epon 828 Di Cy	100 3 250 10	Tacky	OK	33.68^A	[illegible]	[illegible]	[illegible]	1.88×10^6

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RESIN SYSTEM [illegible] TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
42	Butvar RS-31 Epon 828 [illegible] CY	100 3 300 12	Tacky	OK, but whitened in I.D. slightly	32.98[A]	26,[illegible]00[A]	2.23 x 10^6 [A]	33,1[illegible]0[A]	1.26 x 10^6 [A]
43	Butvar RS-31 Epon 828 BF_3	100 3 100 3	Tack free	OK	44.15[A]	16,100[A]	1.34 x 10^6 [A]	10,100[A]	.28 x 10^6 [A]
44	Butvar RS-31 Epon 828 BF_3	100 3 200 6	Tacky	OK	53.17[A]	16,600[A]	1.48 x 10^6 [A]	16,600[A]	.67 x 10^6 [A]
45	Butvar RS-31 Epon 828 BF_3	100 3 250 7.5	Tacky	OK	37.24[A]	24,000[A]	1.90 x 10^6 [A]	23,200[A]	1.16 x 10^6 [A]
46	Butvar RS-31 Epon 828 BF_3	100 3 300 9	Tacky	OK, but whitened in I.D. slightly	37.72[A] 32.74[C]	27,000[A] 41,400[C]	1.98 x 10^6 [A] 3.15 x 10^6 [C]	19,200[A] 63,500[C]	2.03 x 10^6 [A] 2.8 x 10^6 [C]
47	Butvar Santoset Benzoyl peroxide	100 100 8	Tack free	OK	46.08[A]	19,300[A]	1.20 x 10^6 [A]	6,750[A]	.23 x 10^6 [A]
48	Butvar Santoset Benzoyl peroxide	100 200 16	Tack free	OK	41.38[A]	10,700[A]	.55 x 10^6 [A]	6,860[A]	.51 x 10^6 [A]
49	Butvar Santoset Benzoyl peroxide	100 250 20	Tack free	OK	34.05[A]	22,500[A]	1.33 x 10^6 [A]	12,900[A]	1.28 x 10^6 [A]
50	Butvar Santoset Benzoyl peroxide	100 300 24	Tack free	OK, but whitened in I.D. slightly	32.23[A]	31,500[A]	1.58 x 10^6 [A]	13,000[A]	1.43 x 10^6 [A]
51	Butvar RS-31 Santoset Benzoyl peroxide	100 3 100 8	Tack free	OK	46.56[A]	10,700[A]	.74 x 10^6 [A]	3,150[A]	.052 x 10^6 [A]
52	Butvar RS-31 Santoset Benzoyl peroxide	100 3 200 16	Tack free	OK	42.20[A]	21,500[A]	1.25 x 10 [A]	9,140[A]	.5[illegible] x 10 [A]
53	Butvar RS-31 Santoset Benzoyl peroxide	100 3 250 [illegible]	Tack free	OK	31.76[A]	24,700[A]	1.71 x 10^6 [A]	12,700[A]	1.24 x 10^6 [A]

TABLE I
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RESIN SYSTEM SCREENING TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
54	Butvar RS-31 Santoset Benzoyl peroxide	100 3 300 24	Tack free	OK, but whitened in I.D. slightly	31.59^A	26,300^A	1.69 x 10^{6A}	13,700^A	1.72 x 10^{6A}
55	Butvar RS-31 ERL 2256 BF_3	100 3 100 3	Slightly tacky	OK	48.12^A	10,400^A	1.12 x 10^{6A}	15,008^A	.57 x 10^{6A}
56	Butvar RS-31 ERL 2256 BF_3	100 3 200 6	Tacky, sticks to itself	Delaminated	41.24^A	21,100^A	1.57 x 10^{6A}	23,055^A	1.17 x 10^{6A}
57	Butvar RS-31 ERL 2256 BF_3	100 3 250 7.5	Tacky, sticks to itself	Delaminated	37.36^A 36.12^C	29,600^A 35,200^C	2.50 x 10^{6A} 2.92 x 10^{6C}	43,950^A 69,000^C	2.25 x 10^{6A} 3.1 x 10^{6C}
58	Butvar RS-31 ERL 2256 BF_3	100 3 300 9	Tacky, sticks to itself	Delaminated	38.05^A 38.02^C	17,800^A 32,200^C	1.77 x 10^{6A} 3.00 x 10^{6C}	41,160^A 61,500^C	2.01 x 10^{6A} 2.3 x 10^{6C}
59	Butvar RS-31 ERL 2256 Di Cy	100 3 100 4	Tacky	OK, but whitened in I.D.	41.64^A	13,600^A	.96 x 10^{6A}	5,238^A	.17 x 10^{6A}
60	Butvar RS-31 ERL 2256 Di Cy	100 3 200 8	Tacky, sticks to itself	Delaminated	34.42^A	26,100^A	1.79 x 10^{6A}	19,520^A	1.15 x 10^{6A}
61	Butvar RS-31 ERL 2256 Di Cy	100 3 250 10	Tacky, sticks to itself	Delaminated	28.71^A 28.45^C	23,500^A 32,300^C	2.40 x 10^{6A} 3.18 x 10^{6C}	21,750^A 31,000^C	1.79 x 10^{6A} 2.4 x 10^{6C}
62	Butvar RS-31 ERL 2256 Di Cy	100 3 300 12	Tacky, sticks to itself	Delaminated	26.96^A 28.12^C	14,400^A 30,800^C	1.72 x 10^{6A} 2.16 x 10^{6C}	20,910^A 26,000^C	1.22 x 10^{6A} 2.2 x 10^{6C}
63	CANCELLED								
64	CANCELLED								
65	CANCELLED								
66	CANCELLED								
67	CANCELLED								
68	CANCELLED								
69	CANCELLED								
70	CANCELLED								

TABLE I
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RESIN SYSTEM SCREENING TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
71	Blacar RS-31 ERL 2256 BF_3	100 3 100 3	Tack free	OK	39.28^A	32,100^A	1.82×10^{6A}	34,432^A	1.6×10^{6A}
72	Blacar RS-31 ERL 2256 BF_3	100 3 200 6	Tack free	OK	36.78^A	32,800^A	2.04×10^{6A}	39,936^A	1.9×10^{6A}
73	Blacar RS-31 ERL 2256 BF_3	100 3 250 7.5	Tack free	OK	33.31^A 30.18^C	33,400^A 35,500^C	2.27×10^{6A} 2.59×10^{6C}	36,366^A 58,000^C	1.6×10^{6A} 3.0×10^{6C}
74	Blacar RS-31 ERL 2256 BF_3	100 3 300 9	Tack free	OK	34.39^A 30.13^C	28,000^A 36,300^C	1.88×10^{6A} 2.56×10^{6C}	32,562^A 21,600^C	1.4×10^{6A} 1.5×10^{6C}
75	Blacar RS-31 ERL 2256 Di Cy	100 3 100 4	Tack free	OK	39.53^A	33,400^A	1.93×10^{6A}	38,850^A	1.6×10^{6A}
76	Blacar RS-31 ERL 2256 Di Cy	100 3 200 8	Tack free	OK	35.53^A	33,100^A	1.84×10^{6A}	43,043^A	1.9×10^{6A}
77	Blacar RS-31 ERL 2256 Di Cy	100 3 250 10	Tack free	OK	32.53^A 33.22^C	37,500^A 35,000^C	2.12×10^{6A} 2.71×10^{6C}	44,226^A 29,300^C	2.3×10^{6A} 2.7×10^{6C}
78	Blacar RS-31 ERL 2256 Di Cy	100 3 300 12	Tack free	OK	33.89^A 33.02^C	24,200^A 36,800^C	1.78×10^{6A} 2.69×10^{6C}	45,568^A 36,200^C	2.2×10^{6A} 2.0×10^{6C}
79	Blacar RS-31 ERL 4221 BF_3	100 3 100 3	Tack free	OK	41.07^A	24,800^A	1.68×10^{6A}	18,360^A	0.9×10^{6A}
80	Blacar RS-31 ERL 4221 BF_3	100 3 200 6	Tack free	OK	39.71^A	23,200^A	1.51×10^{6A}	16,320^A	1.9×10^{6A}
81	Blacar RS-31 ERL 4221 BF_3	100 3 250 7.5	Tack free	OK	33.99^A 30.35^C	36,000^A 37,100^C	2.18×10^{6A} 3.04×10^{6C}	5,828^A 29,500^C	$.5 \times 10^{6A}$ 2.6×10^{6C}

TABLE I
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RESIN SYSTEM SCREENING TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
82	Blacar RS-31 ERL 4221 BF$_3$	100 3 300 9	Tack free	OK	37.21^{A} 32.48^{C}	-- 39,700^{C}	-- 2.85 x 10^{6C}	3,020^{A} 42,500^{C}	.2 x 10^{6A} 3.0 x 10^{6C}
83	Blacar RS-31 ERL 4221 Di Cy	100 3 100 4	Tack free	OK	36.59^{A}	21,900^{A}	1.36 x 10^{6A}	7,280^{A}	.6 x 10^{6A}
84	Blacar RS-31 ERL 4221 Di Cy	100 3 200 8	Tack free	OK	39.27^{A}	24,000^{A}	1.18 x 10^{6A}	7,000^{A}	.6 x 10^{6A}
85	Blacar RS-31 ERL 4221 Di Cy	100 3 250 10	Tack free	OK	34.2^{A} 29.60^{C}	26,200^{A} 26,000^{C}	1.40 x 10^{6A} --	4,600^{A} 14,300^{C}	.2 x 10^{6A} 1.8 x 10^{6C}
86	Blacar RS-31 ERL 4221 Di Cy	100 3 300 12	Tack free	OK	35.94^{A} 28.82^{C}	18,650^{A} 15,350^{C}	1.12 x 10^{6A} --	5,610^{A} 6,475^{C}	.25 x 10^{6A} .72 x 10^{6C}
87	Butvar DAP Benzoyl peroxide	100 100 8	Tacky, sticks to itself	OK	41.73^{A}	12,900^{A}	.69 x 10^{6A}	5,472^{A}	.16 x 10^{6A}
88	Butvar DAP Benzoyl peroxide	100 200 16	Tacky, sticks to itself	OK, but delaminated easy	33.59^{A}	25,200^{A}	1.71 x 10^{6A}	17,080^{A}	1.12 x 10^{6A}
89	Butvar DAP Benzoyl peroxide	100 250 20	Tacky, sticks to itself	Pulls apart	21.30^{A}	16,400^{A}	1.58 x 10^{6A}	3,300^{A}	.87 x 10^{6A}
90	Butvar DAP Benzoyl peroxide	100 300 24	Tacky, sticks to itself	Pulls apart	21.79^{A}	23,900^{A}	1.66 x 10^{6A}	8,430^{A}	1.26 x 10^{6A}
91	Butvar RS-31 DAP Benzoyl peroxide	100 3 100 8	Tacky, sticks to itself	OK	41.35^{A}	10,100^{A}	.38 x 10^{6A}	684^{A}	.019 x 10^{6A}
92	Butvar RS-31 DAP Benzoyl peroxide	100 3 200 16	Tacky, sticks to itself	Delaminated Pulls apart	24.97^{A}	20,000^{A}	1.20 x 10^{6A}	685^{A}	.028 x 10^{6A}
93	Butvar RS-31 DAP Benzoyl peroxide	100 3 250 20	Tacky, sticks to itself	Delaminated Pulls apart	18.85^{A}	13,300^{A}	.99 x 10^{6A}	5,900^{A}	1.07 x 10^{6A}

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RESIN SYSTEM SCREENING [illegible]

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
94	Butvar PS-31 DAP Benzoyl peroxide	100 3 300 24	Tacky, sticks to itself	Delaminated Pulls apart	17.73^A	18,[illegible]^A	1.20×10^{6A}	[illegible]^A	1.11×10^{6A}
95	Blacar RS-31 DAP t-Butyl perbenzoate	100 3 100 [illegible]	Tack free	OK	36.77^C	^{C}	^{C}	15,928^C	2.33×10^{6C}
96	Blacar RS-31 DAP t-Butyl perbenzoate	100 3 200 8	Tack free	OK	37.49^C	^{C}	^{C}	17,289^C	2.04×10^{6C}
97	Blacar RS-31 DAP t-Butyl perbenzoate	100 3 250	Tack free	OK	35.84^C	^{C}	^{C}	20,355^C	1.93×10^{6C}
98	Blacar RS-31 DAP t-Butyl perbenzoate	100 3 300 12	Tacky	OK	38.89^C	^{C}	^{C}	24,871^C	2.33×10^{6C}
99	Butvar ERL 4221 Di Cy	100 100 4	Tacky, sticks to itself	OK	42.74^A	19,650^A	1.21×10^{6A}	12,584^A	$.56 \times 10^{6A}$
100	Butvar ERL 4221 Di Cy	100 200 8	Tacky, sticks to itself	OK, but whitened in I.D.	23.68^A	Delaminated During Cure^A			
101	Butvar ERL 4221 Di Cy	100 250 10	Tacky, sticks to itself	OK, but whitened in I.D.	24.16^A 24.06^C	Delaminated During Cure^A 35,000^C	2.60×10^{6C}	16,100^C	1.7×10^{6C}
102	Butvar ERL 4221 Di Cy	100 300 12	Tacky, sticks to itself	Delaminated	26.69^A 25.60^C	Delaminated During Cure^A 37,800^C	2.60×10^{6C}	6,350^C	1.1×10^{6C}
103	Butvar ERL 4221 BF_3	100 100 3	Tacky	OK	49.03^A	16,700^A	1.45×10^{6A}	13,734^A	$.7[illegible] \times 10^{6A}$
104	Butvar ERL 4221 BF_3	100 200 6	Tacky	OK, but whitened in I.D.	39.13^A	25,700^A	2.10×10^{6A}	4[illegible],260^A	$1.[illegible] \times 10^{6A}$
105	Butvar ERL 4221 BF_3	100 250 7.5	Tacky	Delaminated	31.88^A 25.36^C	27,900^A 36,300^C	2.47×10^{6A} 2.71×10^{6C}	42,228^A 66,500^C	$2.[illegible] \times 10^{6A}$ $3.[illegible] \times 10^{6C}$
106	Butvar ERL 4221 BF_3	100 300 [illegible]	Tacky	Delaminated	31.31^A 34.[illegible]^C	2[illegible],200^A 39,200^C	2.20×10^{6A} 3.93×10^{6C}	30,422^A [illegible],500^C	1.8×10^{6A} 2.8×10^{6C}

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BASIC SYSTEM SCREENING TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
107	Butvar RS-31 ERL 4221 Di Cy	100 3 100 4	Tacky, sticks to itself	OK, but whitened in I.D.	42.10^A	18,250^A	1.47 x 10^{6A}	5,551^A	.3 x 10^{6A}
108	Butvar RS-31 ERL 4221 Di Cy	100 3 200 8	Tacky, sticks to itself	OK, but whitened in I.D.	32.88^A	28,100^A	1.67 x 10^{6A}	23,200^A	1.09 x 10^{6A}
109	Butvar RS-31 ERL 4221 Di Cy	100 3 250 10	Tacky, sticks to itself	Delaminated	26.52^A 25.60^C	35,000^A 28,250^C	1.95 x 10^{6A} 1.04 x 10^{6C}	28,116^A 6,600^C	1.8 x 10^{6A} .76 x 10^{6C}
110	Butvar RS-31 ERL 4221 Di Cy	100 3 300 12	Tacky, sticks to itself	Delaminated	27.82^A 27.85^C	30,300^A 32,500^C	1.76 x 10^{6A} 1.90 x 10^{6C}	27,819^A 23,400^C	1.75 x 10^{6A} 3.1 x 10^{6C}
111	Butvar RS-31 ERL 4221 BF_3	100 3 100 3	Tacky	OK	47.31^A	17,900^A	1.45 x 10^{6A}	29,014^A	1.16 x 10^{6A}
112	Butvar RS-31 ERL 4221 BF_3	100 3 200 6	Tacky	OK	39.68^A	24,900^A	2.41 x 10^{6A}	38,220^A	1.49 x 10^{6A}
113	Butvar RS-31 ERL 4221 BF_3	100 3 250 7.5	Tacky	OK, but whitened in I.D.	36.87^A 36.68^C	23,800^A 37,700^C	2.35 x 10^{6A} 2.71 x 10^{6C}	52,530^A 65,500^C	2.1 x 10^{6A} 2.8 x 10^{6C}
114	Butvar RS-31 ERL 4221 BF_3	100 3 300 9	Tacky	OK, but whitened in I.D.	31.20^A 29.03^C	24,700^A 46,300^C	2.21 x 10^{6A} 3.37 x 10^{6C}	47,334^A 49,750^C	2.1 x 10^{6A} 2.7 x 10^{6C}
115	Epon 828 Z	100 12.5	Tack free	Would not fold	40.9	39,354	2.5 x 10^6	62,400	2.2 x 10^6
115a	Epon 828 Z	100 12.5	Tack free	Delaminated	56.61	17,850	--	11,000	.86 x 10^6
115b	Epon 828 Z	100 12.5	Tack free	OK, but 2" diam min. bend	79.65	10,300	.48 x 10^6	13,760	.5 x 10^6

TABLE I
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RESIN SYSTEM SCREENING TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
116	Epon 828 Z	100 10	Tack free	Would not fold	35.25	31,000	2.6×10^{6}	14,140	1.7×10^{6}
116a	Epon 828 Z	100 10	Tack free	Delaminated	72.49	12,100	--	25,550	$.56 \times 10^{6}$
116b	Epon 828 Z	100 10	Tack free	OK, but 2" diam. min. bend	76.65	9,550	$.51 \times 10^{6}$	7,308	0.6×10^{6}
117	Butvar DAP t-Butyl perbenzoate	100 100 4	Tacky	OK	30.26C	38,500C	2.36×10^{6}C	48,168C	2.6×10^{6}C
118	Butvar DAP t-Butyl perbenzoate	100 200 8	Tacky, sticks to itself	OK	30.27C	44,200C	2.91×10^{6}C	57,304C	3.3×10^{6}C
119	Butvar DAP t-Butyl perbenzoate	100 250 10	Tacky, sticks to itself	Delaminated	18.66C	46,600C	2.90×10^{6}C	70,738C	3.3×10^{6}C
120	Butvar DAP t-Butyl perbenzoate	100 300 12	Tacky, sticks to itself	Delaminated	23.68C	33,700C	3.46×10^{6}C	80C	3.2×10^{6}C
121	Butvar RS-31 DAP t-Butyl perbenzoate	100 3 100 4	Tacky	OK	29.21C	24,200C	1.28×10^{6}C	14,256C	1.9×10^{6}C
122	Butvar RS-31 DAP t-Butyl perbenzoate	100 3 200 8	Tacky, sticks to itself	OK	21.36C	41,600C	2.72×10^{6}C	43,032C	3.6×10^{6}C
123	Butvar RS-31 DAP t-Butyl perbenzoate	100 3 250 10	Tacky, sticks to itself	Delaminated	24.42C	42,300C	2.74×10^{6}C	38,704C	3.5×10^{6}C
124	Butvar RS-31 DAP t-Butyl pertenzoate	100 3 300 12	Tacky, sticks to itself	Delaminated	22.82C	38,800C	2.82×10^{6}C	29,484C	2.1×10^{6}C
125	Epon 828 Z	100 12.5	Tack free	OK, 7" dia. min. bend	73.89E	E	E	20,374E	$.91 \times 10^{6}$E
126	Butvar RS-31 Epon 828 MNA BDMA	100 3 131.5 118.5 1.31	Tacky, sticks to itself	OK, but surface on I.D. whitened	18.96P 33.32C	36,153P 28,703C	——P 2.1×10^{6}C	48,200P 27,300C	2.79×10^{6}P 2.54×10^{6}C

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RESIN SYSTEM SCREENING TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
127	Butvar RS-31 Epon 828 MNA BDMA	100 3 158 142 1.58	Tacky, sticks to itself	Delaminated	29.53^{C} 24.05^{F}	20,740^{C} 29,038^{F}	1.4 x 10^{6C} 2.2 x 10^{6F}	34,100^{C} 43,200^{F}	2.33 x 10^{6C} 2.73 x 10^{6F}
128	Blacar RS-31 Epon 828 MNA BDMA	100 3 131.5 118.5 1.31	Tacky, sticks to itself	Delaminated	27.95^{C}	10,000^{C}	.85 x 10^{6C}	6,100	.75 x 10^{6C}
129	Blacar RS-31 Epon 828 MNA BDMA	100 3 158 142 1.58	Tacky, sticks to itself	Delaminated	28.06^{C}	13,148^{C}	1.1 x 10^{6C}	7,200	1.08 x 10^{6C}
130	butvar RS-31 Epon 828 Di Cy	100 3 300 9	Tacky, sticks to itself	OK - But Whitens in I.D.	30.31^{C}	44,800^{C}	2.66 x 10^{6C}	55,968^{C}	2.4 x 10^{6C}
131	Butvar RS-31 Epon 828 Di Cy	100 3 300 7.5	Tacky, sticks to itself	OK - But Whitens in I.D.	30.17^{C}	41,200^{C}	2.41 x 10^{6C}	46,332^{C}	2.3 x 10^{6C}
132	Butvar RS-31 Epon 828 Di Cy	100 3 300 6	Tacky sticks to itself	OK - But Whitens in I.D.	28.73^{C}	40,700^{C}	2.60 x 10^{6C}	61,360^{C}	2.5 x 10^{6C}
133	Butvar RS-31 Epon 828 Di Cy	100 3 300 4.5	Tacky sticks to itself	OK - But Whitens in I.D.	30.14^{C}	38,700^{C}	2.73 x 10^{6C}	47,260^{C}	2.3 x 10^{6C}
134	Butvar RS-31 Epon 828 DDS	100 3 300 84				CANCELLED			
135	Butvar RS-31 Epon 828 DDS	100 3 300 45				CANCELLED			
136	Butvar RS-31 Epon 828 DDS	100 3 300 22.5				CANCELLED			
137	Butvar RS-31 Epon 828 DDS	100 3 300 15				CANCELLED			
138	Butvar RS-31 EPON 828 BF_3	100 3 300 7.5	Tacky sticks to itself	OK - But Whitens in I.D.	36.68^{C}	30,000^{C}	2.41 x 10^{6C}	47,047^{C}	2.1 x 10^{6C}

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RESIN SYSTEM SCREENING TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
139	Butvar RS-31 Epon 828 BF_3	100 3 300 5	Tacky sticks to itself	OK - But Whitens in I.D.	35.54	30,900[C]	2.26×10^{6}[C]	53,428[C]	2.2×10^{6}
140	Butvar RS-31 Epon 828 BF_3	100 3 300 2.5	Tacky sticks to itself	OK - But Whitens in I.D.	34.47	32,400	2.78×10^{6}[C]	34,210	1.4×10^{6}
141	Butvar RS-31 Epon 828 BF_3	100 3 300 2	Tacky sticks itself	OK - But Whitens in I.D.	30.85	35,700	2.11×10^{6}	27,200	2.08×10^{6}
142	Butvar RS-31 Epon 828 BF_3	100 3 300 1.5	Tacky sticks to itself	OK - But Whitens in I.D.	25.58	12,800	$.66 \times 10^{6}$	6,660	$.57 \times 10^{6}$
143	Butvar RS-31 Epon 828 BF_3	100 3 300 1	Tacky sticks to itself	OK - But Whitens in I.D.	24.10[C]	16,700[C]	$.25 \times 10^{6}$[C]	660[C]	$.17 \times 10^{6}$[C]
144	Butvar RS-31 Epon 828 BF_3	100 3 300 .5	Tacky sticks to itself	OK - But Whitens in I.D.	25.92[C]	29,500[C]	1.65×10^{6}[C]	8,480[C]	$.83 \times 10^{6}$[C]
145	Butvar RS-31 Epon 828 Di Cy	100 3 300 4	Tacky sticks to itself	OK - But Whitens in I.D.	24.29[C]	45,600[C]	3.37×10^{6}[C]	42,600[C]	2.73×10^{6}[C]
146	Butvar RS-31 Epon 828 Di Cy	100 3 300 3.5	Tacky sticks to itself	OK - But Whitens in I.D.	23.78[C]	33,800[C]	3.04×10^{6}[C]	34,500[C]	2.37×10^{6}[C]
147	Butvar RS-31 Epon 828 Di Cy	100 3 300 3	Tacky sticks to itself	OK - But Whitens in I.D.	24.64[C]	29,500[C]	2.30×10^{6}[C]	36,900[C]	2.56×10^{6}[C]
148	Butvar RS-31 Epon 828 Di Cy	100 3 300 2.5	Tacky sticks to itself	OK - But Whitens in I.D.	25.87[C]	27,500[C]	1.94×10^{6}[C]	21,300[C]	1.89×10^{6}[C]
149	Butvar RS-31 Epon 828 Di Cy	100 3 390 2	Tacky sticks to itself	OK - But Whitens in I.D.	26.35[C]	28,100[C]	2.13	23,400[C]	1.99×10^{6}[C]

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RESIN SYSTEM SCREENING TEST

Test	Material	Parts	Tack	Fold	Resin Content %	Tensile	Tensile Modulus	Flexural	Flexural Modulus
150	Butvar RS-31 Epon 828 Di Cy	100 3 300 1.5	Tacky Sticks to itself	OK - But Whitens in I.D.	25.59^{C}	31,300^{C}	2.16×10^{6} ^{C}	16,500^{C}	1.95×10^{6} ^{C}
151	Butvar RS-31 Epon 828 Di Cy	100 3 300 1	Tacky sticks to itself	OK - But Whitens in I.D.	26.07^{C}	29,400	2.68×10^{6} ^{C}	14,200^{C}	2.03×10^{6} ^{C}
152	Butvar RS-31 Epon 828 Di Cy	100 3 300 .5	Tacky sticks to itself	OK - But Whitens in I.D.	28.16^{C}	26,800^{C}	2.23×10^{6} ^{C}	29,600^{C}	2.17×10^{6} ^{C}

A - Ambient Pressure During Oven Cure
B - Postcure and Retested
C - 30 psi Pressure During Cure
D - Ambient Pressure During Oven Cure, Postcure, and Retested
E - Made with 2P122 Cloth
F - 30 psi Pressure During Cure, Postcured, 500°F, 5 hr.

TABLE II
Page 1 of 2

WING TANK AGEING TEST 165°F

Test No.	Material	Parts	Date Specimen Fabricated	Test Start	Test End	Est Life 165°F	Remarks
13	PVC+RS31 EPON 828 DICY	100 250 10	6-23-67	8-15-67	10-2-67	<49 Days	A,B,C, Delaminated
16	PVC+RS31 EPON 828 BF_3	100 250 7.5	6-23-67	8-15-67	10-2-67	<49 Days	A,B,C, Delaminated
25	BUTVAR EPON 828 DICY	100 250 10	6-30-67	8-15-67	10-2-67	<49 Days	A,B,C, Delaminated
29	BUTVAR EPON 828 BF_3	100 250 7.5	6-30-67	8-15-67	10-2-67	<49 Days	C Delaminated
33	BUTVAR ERL-2256 BF_3	100 250 7.5	7-14-67	8-15-67	11-1-67	<79 Days	C, D Delaminated
37	BUTVAR ERL-2256 DICY	100 250 10	7-14-67	8-15-67	11-1-67	<79 Days	C, D Delaminated
73	PVC+RS31 ERL-2256 BF_3	100 250 7.5	7-24-67	8-15-67	1-2-68	<139 Days	C, D, E, F, Delamin.
77	PVC+RS31 ERL-2256 DICY	100 250 10	7-24-67	8-15-67	12-4-67	<112 Days	C, D, & E Delaminated
81	PVC+RS31 ERL-4221 BF_3	100 250 7.5	7-25-67	8-15-67	12-4-67	<112 Days	C, D, E Delaminated
85	PVC+RS31 ERL-4221 DICY	100 250 10	7-25-67	8-15-67	5-9-68	<269 Days	G Delaminated
98	PVC DAP t-BUTYL PERBENZOATE	100 250 12	8-9-67	8-15-67	5-9-68	<269 Days	G Delaminated
101	BUTVAR ERL-4221 DICY	100 250 10	7-20-67	8-15-67	5-9-68	<269 Days	G Delaminated
105	BUTVAR ERL-4221 BF_3	100 250 7.5	7-20-67	8-15-67	10-2-67	<49 Days	A,B,C, Delaminated
127	BUTVAR+RS31 EPON 828 MNA BDMA	100 158 142 1.38	8-28-67	8-28-67	1-2-68	<128 Days	C, D, E, F
130	BUTVAR+RS31 EPON 828 DICY	100 300 9	9-1-67	9-1-67	11-1-67	<60 Days	C, D Delaminated
131	BUTVAR+RS31 EPON 828 DICY	100 300 7.5	9-1-67	9-1-67	11-1-67	<60 Days	C, D Delaminated
132	BUTVAR+RS31 EPON 828 DICY	100 300 6	9-1-67	9-1-67	11-1-67	<60 Days	C, D Delaminated
133	BUTVAR+RS31 EPON 828 DICY	100 300 4.5	9-1-67	9-1-67	11-1-67	<60 Days	C, D Delaminated

Table II Continued
WING TANK
AGING TEST 165°F

Test No.	Material	Parts	Date Specimen Fabricated	Test Start	End	Pot Life 165°F	Remarks
138	BUTVAR+RS31 EPON 828 BF_3	100 300 7.5	9-1-67	9-1-67	11-1-67	<60 Days	C, D Delaminated
139	BUTVAR+RS31 EPON 828 BF_3	100 300 5	9-1-67	9-1-67	11-1-67	<60 Days	C, D Delaminated
140	BUTVAR+RS31 EPON 828 BF_3	100 300 2.5	9-1-67	9-1-67	11-1-67	<60 Days	C, D Delaminated
141	BUTVAR+RS31 EPON 828 BF_3	100 300 2	9-11-67	9-11-67	1-2-68	<112 Days	D, F Delaminated
142	BUTVAR+RS31 EPON 828 BF_3	100 300 1.5	9-11-67	9-11-67	1-2-68	<112 Days	F Delaminated
143	BUTVAR+RS31 EPON 828 BF_3	100 300 1	9-11-67	9-11-67	5-8-68	>242 Days	G Moldable
144	BUTVAR+RS31 EPON 828 BF_3	100 300 .5	9-11-67	9-11-67	5-9-68	>242 Days	G Moldable
145	BUTVAR+RS31 EPON 828 DICY	100 300 4	9-12-67	9-12-67	11-1-67	<49 Days	D Delaminated
146	BUTVAR+RS31 EPON 828 DICY	100 300 3.5	9-12-67	9-12-67	11-1-67	<49 Days	D Delaminated
147	BUTVAR+RS31 EPON 828 DICY	100 300	9-12-67	9-12-67	12-4-67	<85 Days	D, E, Delaminated
148	BUTVAR+RS31 EPON 828 DICY	100 300 2.5	9-12-67	9-12-67	1-2-68	<110 Days	F Delaminated
149	BUTVAR+RS31 EPON 828 DICY	100 300 2	9-12-67	9-12-67	12-4-67	<83 Days	D, E, Delaminated
150	BUTVAR+RS31 EPON 828 DICY	100 300 1.5	9-12-67	9-12-67	5-9-68	>241 Days	G Moldable
151	BUTVAR+RS31 EPON 828 DICY	100 300 1	9-12-67	9-12-67	5-9-68	>241 Days	G Moldable
152	BUTVAR+RS31 EPON 828 DICY	100 300 .5	9-12-67	9-12-67	5-9-68	>241 Days	G Moldable
MRC-MS-001			11-2-67	12-12-67	5-9-68	>149 Days	G Moldable

A,B,C = Parts stiffened during aging test

A = 8-25-67 Placed PC. of test specimen in 300°F oven to check for softening and placed in 400°F press at 30psi to check for flow. All checked O.K.

B = 9-6-67 Rechecked

G = 5-9-68 Rechecked

C = 10-2-67 Rechecked

D = 11-1-67 Rechecked

E = 12-4-67 Rechecked

F = 1-2-68 Rechecked

NOTE: For each day a specimen is subjected to 165°F. It is equal to approximately 13 days allowing 16 hrs. at 85°F, 3 hrs to go from 85°F to 125°F, 2 hrs at 125°F and 3 hrs to go back to 85°F.

49 days at 165°F = 21 months at new schedule
79 days at 165°F = 34 months at new schedule
60 days at 165°F = 26 months at new schedule
83 days at 165°F = 36 months at new schedule
85 days at 165°F = 36 months at new schedule
110 days at 165°F = 47 months at new schedule
112 days at 165°F = 48 months at new schedule
128 days at 165°F = 55 months at new schedule
139 days at 165°F = 60 months at new schedule
183 days at 165°F = 79 months at new schedule

149 days at 165°F = 64 months at new schedule
241 days at 165°F = 103 months at 58 schedule
242 days at 165°F = 103 months at new schedule
256 days at 165°F = 110 months at new schedule
269 days at 165°F = 115 months at new schedule

TABLE III

STARTED 10:00 A.M. 9-5-67
TAKEN OUT 11:00 A.M. 9-20-67

WING TANK JP-4 FUEL TEST

Test No	Weight Before	Weight After 15 Days	% Increase In Weight	Barcol Before	Barcol After 15 Days	Remarks
14A-1	4.6942	4.6975	.07	73	85	
26-1	2.7074	2.7166	.34	98	80	
30-1	3.1843	3.2006	.51	73	81	
34-1	3.1029	3.1065	.12	93	65	
38-1	4.5366	4.5414	.11	60	83	
46-1	2.3353	2.3401	.21	94	73	
58-1	4.4215	4.4235	.05	76	87	
62-1	2.7393	2.7439	.17	75	59	
73-1	2.9709	2.9736	.09	93	85	
78-1	5.3127	5.3141	.03	94	73	
82-1	2.9992	2.9999	.02	83	77	
86-1	3.3170	3.3164	--	27	36	Weight Loss
102-1	3.2204	3.2327	.38	42	69	
106-1	3.0002	3.0031	.10	97	92	
110-1	4.8372	4.8552	.37	73	67	
114-1	3.3796	3.3851	.16	73	73	
120	2.5603	2.5763	.62	82	84	
123	3.1728	3.1841	.36	88	88	

TABLE IV

REINFORCEMENT SCREENING TEST

		% Resin Content	Tensile	Tensile Mod.	Flex.	Flex. Mod.	Type Fabric
I	A	35.40	32,571	2.8×10^6	55,728	2.4×10^6	181-A1100 Finish
	B	35.30	34,455	2.5×10^6	52,288	2.3×10^6	
	C	29.83	32,727	2.7×10^6	55,909	2.3×10^6	
	D	35.50	33,714	2.5×10^6	56,511	2.4×10^6	
	E	35.71	33,714	2.5×10^6	54,352	2.3×10^6	
	Avg.	34.3480	33,436	2.6×10^6	54,958	2.3×10^6	
II	A	32.24	24,444	2.7×10^6	47,440	2.9×10^6	2P 183-Volan A Finish
	B	28.16	18,077	2.3×10^6	45,584	2.9×10^6	
	C	28.34	26,667	2.7×10^6	45,045	2.8×10^6	
	D	28.49	26,923	2.9×10^6	43,428	2.8×10^6	
	E	27.95	27,593	3.0×10^6	45,360	2.7×10^6	
	Avg.	28.8760	24,740	2.7×10^6	45,371	2.8×10^6	
III	A	35.29	27,900	2.16×10^6	56,635	2.4×10^6	2P 184-Volan A Finish
	B	36.70	33,300	2.48×10^6	51,465	2.3×10^6	
	C	36.88	4,500	2.43×10^6	51,840	2.3×10^6	
	D	37.19	33,700	2.79×10^6	54,288	2.1×10^6	
	E	34.62	33,100	2.48×10^6	54,036	2.4×10^6	
	Avg.	36.1360	32,500	2.47×10^6	53,653	2.3×10^6	
IV	A	33.15	25,800	1.95×10^6	32,775	1.9×10^6	2P 495-Volan A Finish
	B	32.04	23,800	1.95×10^6	35,000	1.9×10^6	
	C	32.21	22,200	2.35×10^6	34,290	1.9×10^6	
	D	32.19	26,100	2.16×10^6	35,000	1.9×10^6	
	E	32.23	25,800	1.97×10^6	34,125	1.9×10^6	
	Avg.	32.3640	24,700	2.08×10^6	34,238	1.9×10^6	
V	A	39.05	24,000	2.1×10^6	35,900	1.7×10^6	KC-2208 Woven Roving
	B	36.95	28,600	2.1×10^6	42,200	2.0×10^6	
	C	35.99	24,300	2.0×10^6	40,500	1.9×10^6	
	D	39.57	27,100	2.2×10^6	43,900	2.0×10^6	
	E	38.10	23,650	2.3×10^6	39,400	1.8×10^6	
	Avg.	37.932	25,530	2.1×10^6	40,400	1.9×10^6	
VI	A	34.77	25,600	2.52×10^6	51,834	2.4×10^6	918 Volan A Finish Hi Modulus Weave
	B	35.40	28,000	2.68×10^6	51,200	2.5×10^6	
	C	36.19	29,300	2.50×10^6	50,700	2.6×10^6	
	D	35.07	30,200	2.63×10^6	52,430	2.5×10^6	
	E	36.50	30,400	2.63×10^6	49,400	2.6×10^6	
	Avg.	35.6060	28,700	2.59×10^6	51,112	2.5×10^6	

TABLE V
SUMMARY OF VARIOUS APPROACHES

APPROACH	1st PRIORITY FOLDABILITY	TABLE V 2nd PRIORITY DEPLOYMENT	3rd PRIORITY WEIGHT	4th PRIORITY SHELF LIFE
1. Thermoelastic system with glass reinforcement.	Very stiff and difficult to fold but will fold to a 1" minimum bend radius if 80% resin is used.	This system requires 250°F for 1 hour to uniformly heat and a minimum of 15 p.s.i. internal pressure.	This unit will weigh from 280 lbs. to 420 lbs.	The shelf life has not been checked But we believe it to be less than 5 years.
2. Thermoelastic system with nylon or fortisan	This system will still be stiff and difficult to fold but will fold to a 7/8" bend radius if 80% resin is used.	This system requires 250°F for 1 hour to uniformly heat and a minimum of 15 p.s.i. internal pressure.	This unit will weigh from 350 lbs. to 500 lbs.	The shelf life has not been checked. But we believe it to be less than 5 years.
3. Irreversable system 181 glass cloth. 3/4 stoichiometric (DICY), 1/4 Butvar.	This system will bend at room temperature back on itself with a slight I.D. whitening.	This system will require a contoured heating blanket to cure the resin system 325°F for 1 1/2 hrs. at 30 p.s.i. internal pressure.	This unit will weigh approximately 140 lbs.	The shelf life is now in process of being checked, but we believe it to be greater than 1 year.
4. Irreversable system same as approach #3 except step cure cycle during deployment.	This system will bend at room temperature back on itself with a slight I.D. whitening.	This system will not require a contoured heating blanket, just a heating blanket to cure the resin system. 2 hour at 200°F 1 hour at 250°F 1 1/2 hour at 325°F	This unit will weigh approximately 140 lbs.	The shelf life is now in process of being checked, but we believe it to be greater than 1 year.
5. Irreversable system same as approach #3 except increased the Butvar to 50%.	This system will bend at room temperature back on itself with a slight I.D. whitening.		This unit will weigh from 200 to 300 lbs.	The shelf life is now in process of being checked, but we believe it to be greater than 1 year.
6. Irreversable system filament wound, 3/4 stoichiometric (DICY), 1/4 Butvar.	This system will bend at room temperature back on itself with a slight I.D. whitening.	This system will only require a heating blanket to cure the resin system 1 1/2 hrs at 325°F with 100 p.s.i. internal pressure.	This unit will weigh approximately 110 lbs.	The shelf life is now in process of being checked, but we believe it to be greater than 1 year.
7. T R W system - 181 glass cloth. Note: This material not available for use in the wing tank program.	Similar to our irreversable system but may be a problem holding plies together in preform. Plies dry as paper, no tack.	This system will require a method of curing at 30 p.s.i. Similar to approach #3. 15 minute cure at 325°F.	This unit will weigh approximately 150 lbs.	The shelf life has not been checked, but T R W believes it to be approximately 1 year

TABLE V[illegible]

WING TANK AGING TEST 24 HOUR CYCLE

Test No.	Material	Parts	Date Specimen Fabricated	Test Start	Test End	Shelf Life	Remarks
16	BLACAR	100	6-23-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	EPON 828	200					
	BF_3	6					
18	BLACAR	100	6-23-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	EPON 828	300					
	BF_3	9					
30	BUTVAR	100	6-30-67	10-5-67		1-22-69	Still Good
	EPON 828	300					
	BF_3	9					
34	BUTVAR	100	7-14-67	10-5-67		1-22-69	Still Good
	ERL 2256	300					
	BF_3	9					
38	BUTVAR	100	7-14-67	10-5-67		1-22-69	Still Good
	ERL 2256	300					
	DICY	12					
46	BUTVAR	100	7-17-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	EPON 828	300					
	BF_3	9					
61	BUTVAR	100	7-17-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	ERL 2256	250					
	DICY	10					
74	BLACAR	100	7-24-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	ERL 2256	300					
	BF_3	9					
77	BLACAR	100	7-24-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	ERL 2256	250					
	DICY	10					
81	BLACAR	100	7-25-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	ERL 4221	250					
	BF_3	7.5					
85	BLACAR	100	7-25-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	ERL 4221	250					
	DICY	10					
101	BUTVAR	100	7-20-67	10-5-67		1-22-69	Still Good
	ERL 4221	250					
	DICY	10					
110	BUTVAR	100	7-21-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	ERL 4221	300					
	DICY	12					
113	BUTVAR	100	7-21-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	ERL 4221	250					
	BF_3	7.5					
118	BUTVAR	100	8-17-67	10-5-67		1-22-69	Still Good
	DAP	200					
	t-BUTYL PERBENZOATE	8					
126	BUTVAR	100	8-25-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	EPON 828	131.5					
	MNA	118.5					
	BDMA	1.31					
127	BUTVAR	100	8-25-67	10-5-67		1-22-69	Still Good
	RS-31	3					
	EPON 828	158					
	MNA	142					
	BDMA	1.58					

16 hrs at 85°F; 3 hrs to go from 85°F to 125°F; 2 hrs at 125°F; 3 hrs to go back to 85°F

Table VI Continued

134	BUTVAR RS-31 EPON 828 DICY	100 3 300 9	8-31-67	10-5-67	[illegible]	Still Good
135	BUTVAR RS-31 EPON 828 DICY	100 3 300 7.5	8-31-67	10-5-67	1-22-69	Still Good
136	BUTVAR RS-31 EPON 828 DICY	100 3 300 6	8-31-67	10-5-67	1-22-69	Still Good
137	BUTVAR RS-31 EPON 828 DICY	100 3 300 4.5	8-31-67	10-5-67	1-22-69	Still Good
138	BUTVAR+RS-31 EPON 828 BF_3	100 300 7.5	9-1-67	10-5-67	1-22-69	Still Good
139	BUTVAR+RS-31 EPON 828 BF_3	100 300 5	9-1-67	10-5-67	1-22-69	Still Good
140	BUTVAR+RS-31 EPON 828 BF_3	100 300 2.5	9-1-67	10-5-67	1-22-69	Still Good
141	BUTVAR+RS-31 EPON 828 BF_3	100 300 2	9-11-67	10-5-67	1-22-69	Still Good
142	BUTVAR+RS-31 EPON 828 BF_3	100 300 1.5	9-11-67	10-5-67	1-22-69	Still Good
143	BUTVAR+RS-31 EPON 828 BF_3	100 300 1	9-11-67	10-5-67	1-22-69	Still Good
144	BUTVAR+RS-31 EPON 828 BF_3	100 300 .5	9-11-67	10-5-67	1-22-69	Still Good
145	BUTVAR+RS-31 EPON 828 DICY	100 300 4	9-12-67	10-5-67	1-22-69	Still Good
146	BUTVAR+RS-31 EPON 828 DICY	100 300 3.5	9-12-67	10-5-67	1-22-69	Still Good
147	BUTVAR+RS-31 EPON 828 DICY	100 300 3	9-12-67	10-5-67	1-22-69	Still Good
148	BUTVAR+RS-31 EPON 828 DICY	100 300 2.5	9-12-67	10-5-67	1-22-69	Still Good
149	BUTVAR+RS-31 EPON 828 DICY	100 300 2	9-12-67	10-5-67	1-22-69	Still Good
150	BUTVAR+RS-31 EPON 828 DICY	100 300 1.5	9-12-67	10-5-67	1-22-69	Still Good
151	BUTVAR+RS-31 EPON 828 DICY	100 300 1	9-12-67	10-5-67	1-22-69	Still Good
152	BUTVAR+RS-31 EPON 828 DICY	100 300 .5	[illegible]	10-5-67	1-22-69	Still Good
MRC-BRC-251			11-2-67	12-6-67	1-22-69	Still Good

TABLE VII

PHYSICAL TESTING

OF

ZONE CURING

CORDO ROLL #	TEST PANEL	SPECIFIC GRAVITY	% RESIN CONTENT	FLEXURAL 0° PSI	FLEXURAL MODULUS 0° 10^6 PSI
4354	5-1	1.87	28.25	84,700	3.62
4354	5-2			84,000	3.64
4354	5-3	1.88	28.51	84,000	3.53
4354	5-4			83,200	3.65
4354	5-5	1.89	28.31	78,300	3.65
4354	5-6			72,400	3.55
4354	5-7	1.89	27.86	85,800	3.65
4354	5-8			75,800	3.62
4354	5-9	1.89	27.51	88,300	3.77
Average		1.88	28.09	81,900	3.64

TABLE VIII

"EXPANDABLE RIGIDIZABLE WING TANK MATERIALS AND DESIGN DEVELOPMENT"

List of Physical Tests

(Revision A 11-17-67)

All tests to be run at ambient temperature.

Test	Total No. of Specimens To Be Tested (A)	Specification
*Tensile	15 x 3 = 45	ASTM D 638-64T
*Tensile Modulus	15 x 3 = 45	ASTM D 638-64T
*Elongation	15 x 3 = 45	ASTM D 638-64T
*Compression	15 x 3 = 45	ASTM D 695-63T
*Compression Modulus	15 x 3 = 45	ASTM D 695-63T
*Flexural	15 x 3 = 45	ASTM D 790-66
*Flexural Modulus	15 x 3 = 45	ASTM D 790-66
*Shear (notched)	15 x 3 = 45	ASTM D 2345-65T
*Bearing	15 x 3 = 45	ASTM D 953-54
*Modulus of Rigidity	15	ASTM D 1043-61T
Resin Content	20 x 5 = 100 (B)	Fed. Test Method Std. No. 406-7061
Specific Gravity	20 x 5 = 100 (B)	ASTM D 792-64T

* = Properties will be measured at angles of loading of 0°, 45° and 90° to the warp direction of the fabric.

A 15 = 5 Panels x three warp directions*.

3 = Three specimens each.

20 = Total of 20 test panels.

5 = Total test specimens from each panel.

Table IX

GENERAL PHYSICAL PROPERTY TESTS (SPECIMENS CURED AT 325°F FOR 3 HOURS)

CORDO ROLL #	TEST PANEL	SPECIFIC GRAVITY	% RESIN CONTENT	ASTM D638-64T TENSILE-PSI 0°	45°	90°	ASTM D638-64T TENSILE MODULUS 10^6 PSI 0°	45°	90°	ASTM D638-64T ELONGATION - % 0°	45°	90°
4342	1	1.74	31.40	48,100	25,200	41,700	3.4	2.0	2.5	1.7	10.2	---
		1.68	34.04	44,800	25,300	42,000	3.0	1.9	2.7	1.5	9.4	1.8
		1.77	30.34	46,600	25,300	38,600	2.9	---	2.5	1.6	---	1.6
		1.71	31.31									
		1.62	31.58									
		Avg. 1.70	31.73									
4345	1	1.78	30.11	47,800	21,800	36,400	3.4	1.9	3.2	1.4	5.3*	1.4
		1.70	31.14	47,800	21,400	37,500	3.2	1.7	2.5	1.6	5.4	1.5
		1.77	29.57	47,800	22,100	38,600	3.1	2.0	2.6	1.7	4.9	1.6
		1.73	31.43									
		1.72	29.95									
		Avg. 1.74	30.44									
4348	1	1.72	29.10	45,200	25,000	39,600	3.4	1.6	3.5	1.5	11.2*	1.3
		1.74	30.31	53,700	25,000	43,600	3.0	1.7	3.3	1.9	10.1*	1.5*
		1.78	29.21	51,100	25,200	42,900	3.4	2.9	3.1	1.6	9.4*	1.7
		1.71	30.82									
		1.75	29.07									
		Avg. 1.74	29.70									
4351	1	1.73	30.15	46,000	25,900	49,300	3.5	---	3.3	1.4	---	1.4
		1.77	29.54	45,000	25,500	40,000	3.6	1.6	2.7	1.3	12.5	1.6
		1.72	30.83	45,700	25,200	42,100	4.0	1.6	3.0	1.4	10.3*	1.4
		1.78	30.06									
		1.74	30.53									
		Avg. 1.75	30.22									
4354	1	1.77	29.16	46,800	24,600	40,000	3.5	1.6	2.6	1.3	9.3*	1.7
		1.77	29.90	51,000	25,000	45,000	3.0	1.6	2.4	1.9	10.5	2.1*
		1.79	28.43	52,500	25,200	36,600	3.4	1.3	2.8	1.8	8.9*	1.5
		1.79	29.35									
		1.81	30.23									
		Avg. 1.79	29.41									
Total Avg.		Avg. 1.74	30.30	48,060	24,513	40,926	3.32	1.80	2.85	1.57	8.82	1.54

* Not Averaged - Gage Slipped

Table IX (Continued)

CORDO ROLL #	TEST PANEL	ASTM D695-63T COMPRESSION - PSI 0°	45°	90°	ASTM D695-63T COMPRESSION MODULUS** 0°	45°	90°
4342	1	51,300*	15,200	44,600	2.37*	1.55	2.48
		55,400	15,700	48,200	2.52	1.49	2.48
		47,500	15,000	46,300	2.31	1.51	2.52
4345	1	52,200	17,000	46,400*	[illegible]	1.58	2.46
		47,900	16,400	---	2.42	1.60	--
		54,800	14,600	48,200	2.52	1.64	2.52
4348	1	52,700	16,300	46,200	2.69	1.53	2.52
		54,600	17,000	47,200	2.68	1.60	2.48
		55,300	16,700	46,600	2.54	1.72	2.60
4351	1	54,300	15,700	50,000	2.58	1.58	2.54
		49,200	15,600	49,100	2.44	1.55	2.52
		52,200	15,200	47,800	2.54	1.58	2.39
4354	1	49,100	14,500	40,200	2.79	1.64	2.29
		55,700	17,500	44,700	2.65	1.58	2.35
		51,400	16,000	43,100	2.58	1.60	2.51
Total Avg.		52,307	15,900	46,323	2.54	1.57	2.46

*Not Averaged - Specimen Buckled During Test.
**Revision A

Table IX (Continued)

CORD ROLL #	TEST PANEL	SPECIFIC GRAVITY	% RESIN CONTENT	ASTM D790-66 FLEXURAL-PSI 0°	45°	90°	ASTM D-790-66 FLEXURAL MODULUS 10⁶ PSI 0°	45°	90°	ASTM D953-54 BEARING TENSION LOAD PSI 0°	45°	90°
4342	2	1.62	34.61	68,400	26,100	53,900	2.71	1.21	2.44	41,100	41,200	40,000
		1.61	36.06	65,000	25,000	54,000	2.64	1.41	2.45	40,800	40,600	38,800
		1.58	33.12	61,900	26,300	51,900	2.95	1.27	2.34	41,700	40,000	37,900
		1.60	36.37									
		1.59	36.46									
		Avg. 1.60	35.32									
4345	2	1.64	36.10	65,900	30,500	57,700	2.62	1.51	2.73	43,400	42,100	45,000
		1.63	36.06	66,500	30,300	55,900	2.66	1.43	2.76	42,400	44,100	43,100
		1.68	35.57	65,200	29,000	61,000	2.55	1.24	2.78	45,900	44,100	42,800
		1.60	36.99									
		1.65	34.95									
		Avg. 1.64	35.93									
4348	2	1.80	28.73	77,000	28,100	69,800	3.20	1.85	3.30	51,400	48,600	51,900
		1.71	29.82	77,200	28,100	69,900	3.20	1.79	3.33	51,800	49,300	51,900
		1.77	29.27	77,600	28,300	66,300	3.20	1.87	3.38	47,900	51,100	48,600
		1.76	27.80									
		1.71	30.58									
		Avg. 1.75	29.24									
4351	2	1.79	29.98	75,700	27,300	67,500	3.27	1.82	3.19	52,900	45,300	46,400
		1.71	30.75	74,800	27,400	69,000	3.19	1.75	3.22	48,900	46,300	48,600
		1.74	29.15	73,800	26,900	70,000	3.20	1.76	3.11	49,300	43,000	48,900
		1.76	28.61									
		1.77	29.49									
		Avg. 1.75	29.60									
4354	2	1.74	30.52	73,100	28,400	65,600	3.18	1.82	3.00	51,800	50,000	49,300
		1.75	28.85	77,300	27,700	69,500	3.39	1.94	3.09	---	47,900	50,000
		1.81	29.34	76,200	27,600	68,200	3.25	1.73	3.14	51,800	51,100	49,300
		1.76	28.13							47,221	45,646	46,166
		1.78	29.72									
		Avg. 1.77	29.31									
Total Avg.		1.70	31.88	71,706	27,800	63,547	3.01	1.62	2.95	9,449	8,590	8,417

Table IX (Continued)

CORDO ROLL #	TEST PANEL		SPECIFIC GRAVITY		% RESIN CONTENT	ASTM D2345-65T SHEAR (NOTCH) - INTERLAMINAR 0°	45°	90°
4342	4		1.60		36.72	2620*	1980*	2260*
			1.66		36.26	2160*	1960*	2020
			1.65		34.75	2340	2040*	2300*
			1.63		34.57			
			1.60		36.43			
		Avg.	1.63	Avg.	35.75			
4345	4		1.64		34.35	2020	1860*	2110
			1.67		36.17	2200	2100	2390*
			1.67		33.95	2210	2020	1970
			1.64		34.86			
			1.67		35.62			
		Avg.	1.66	Avg.	34.99			
4348	4		1.80		29.82	1910	1920	2170*
			1.71		30.22	1820*	1960	2120
			1.79		28.41	2310	1920	2210*
			1.80		30.01			
			1.70		31.42			
		Avg.	1.76	Avg.	29.77			
4351	4		1.78		29.32	2250	1690	2360*
			1.74		30.49	2280	1960	2310*
			1.79		30.60	2310	1920	2630*
			1.82		30.17			
			1.73		30.24			
		Avg.	1.77	Avg.	30.16			
4354	4		1.81		30.14	2620*	2160*	2090
			1.73		31.19	2290	1910	2350
			1.77		28.61	2280	1930	2210
			1.73		30.53			
			1.78		31.10			
		Avg.	1.76	Avg.	30.31			
Total Avg.			1.72		32.20	2218	1933	2135
Net Avg.			1.73		31.46			

*Not Averaged - Not Clean Interlaminter Shear

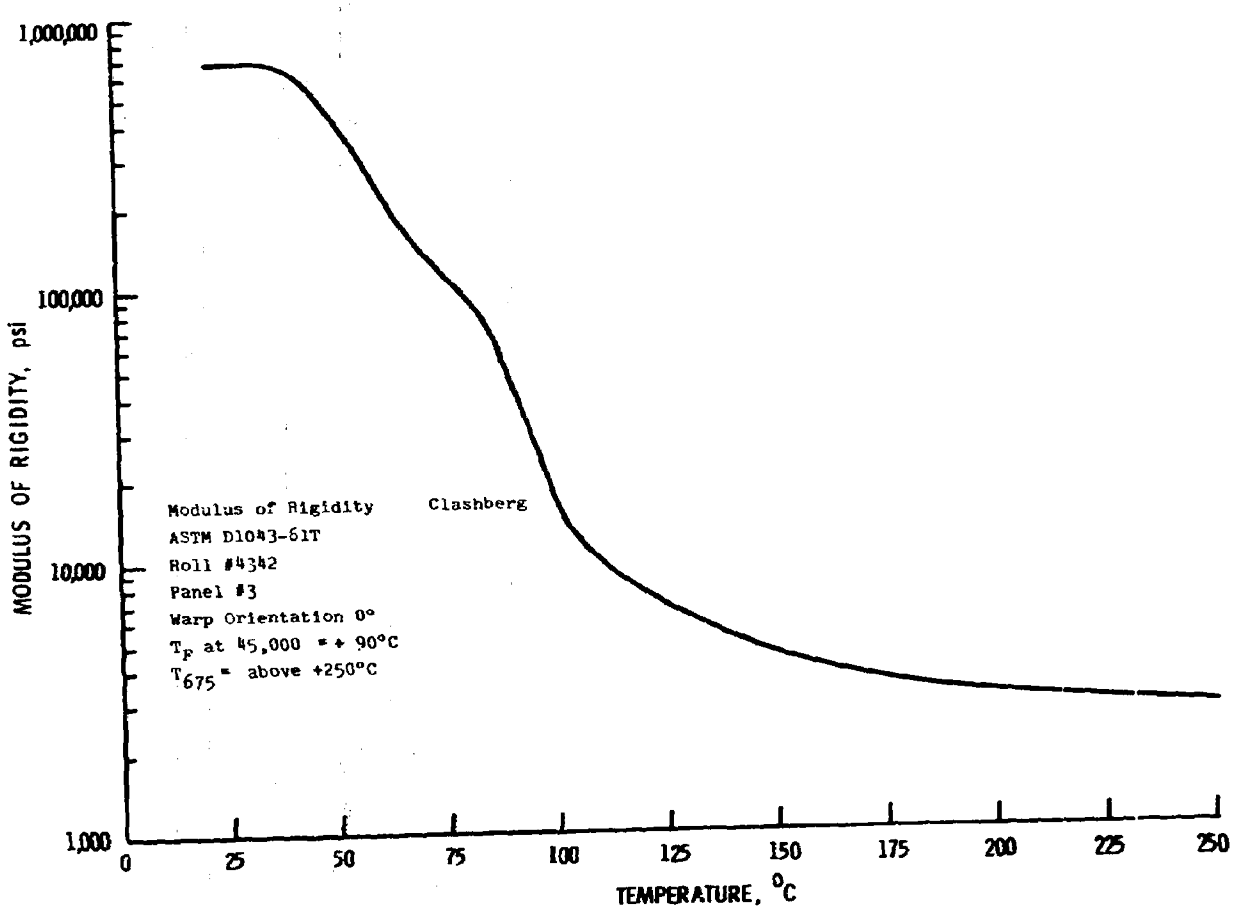


TABLE X
CLASHBERG MODULUS OF RIGIDITY

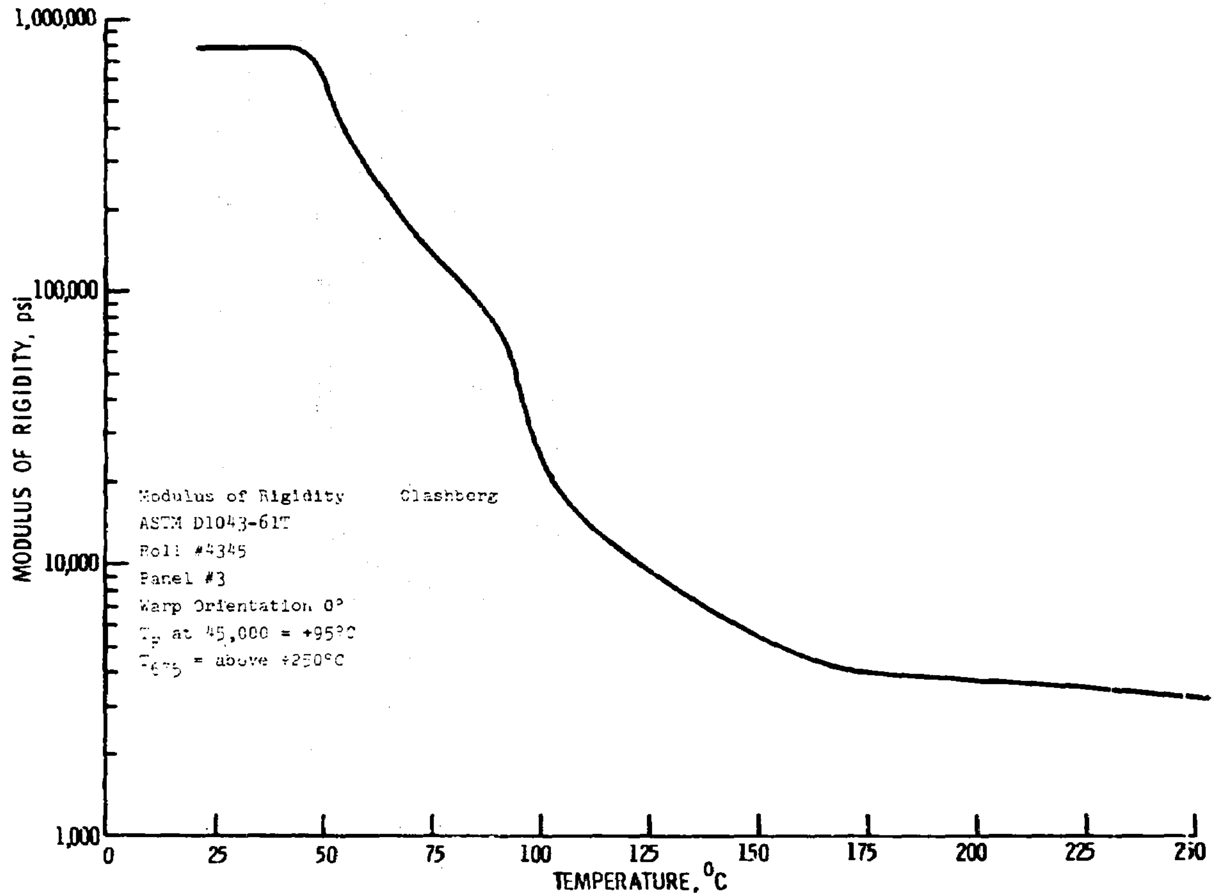
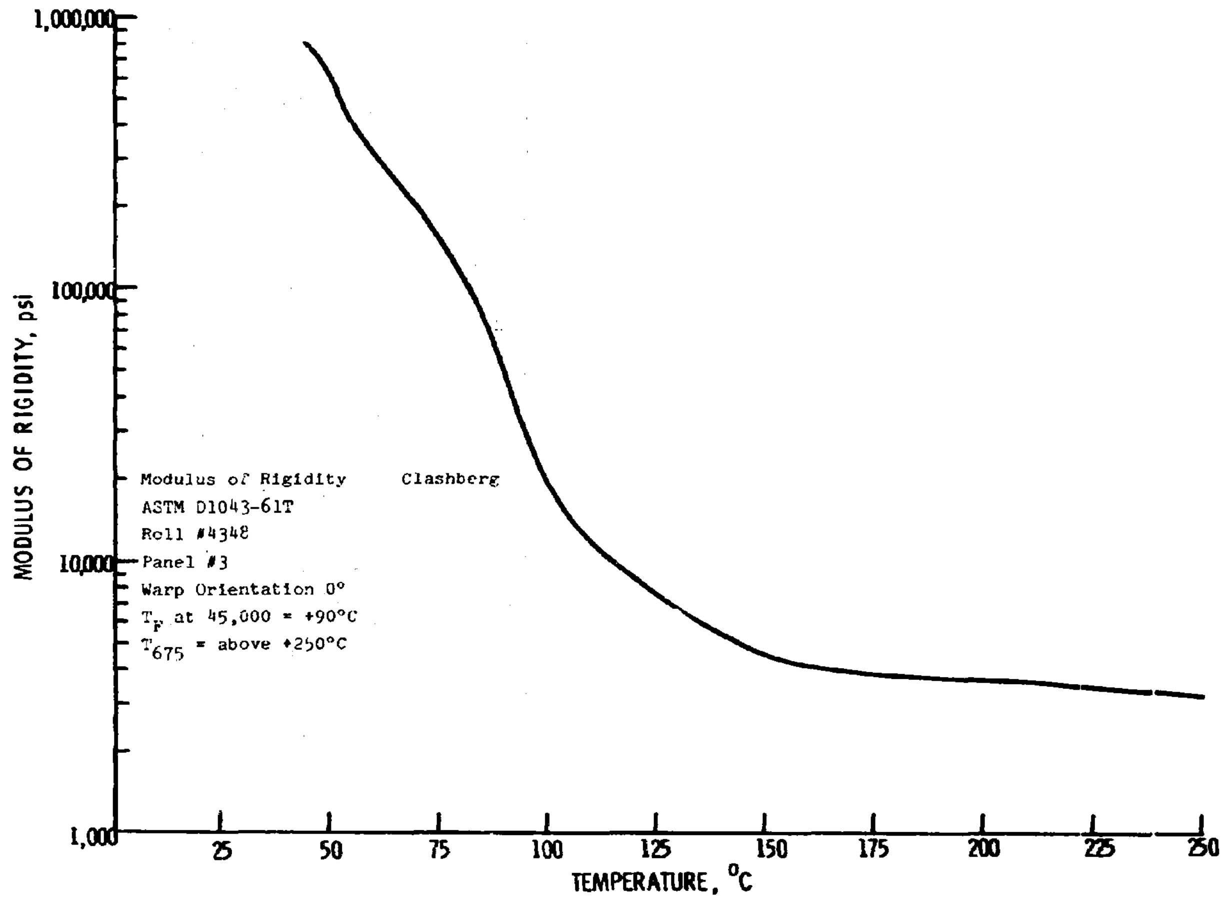


TABLE X CONTINUED



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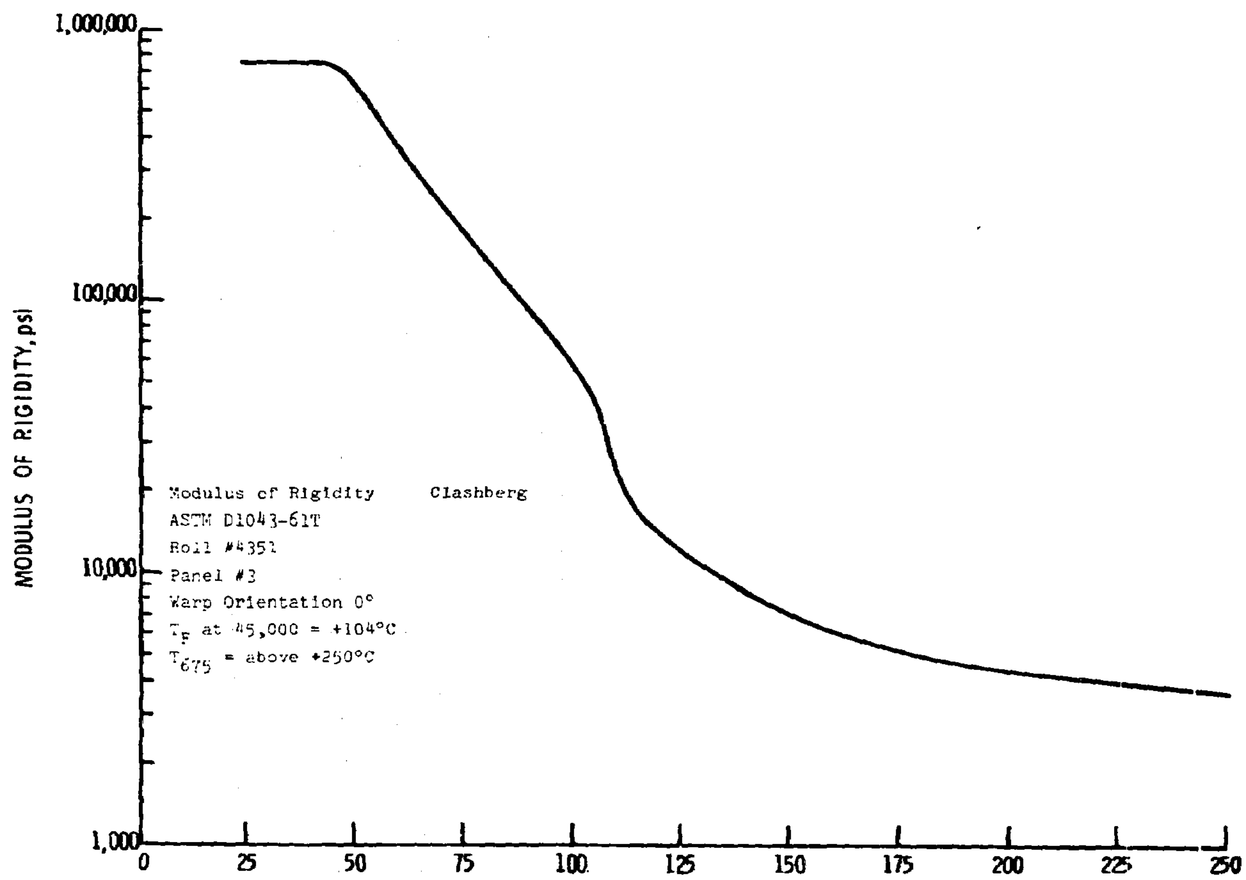

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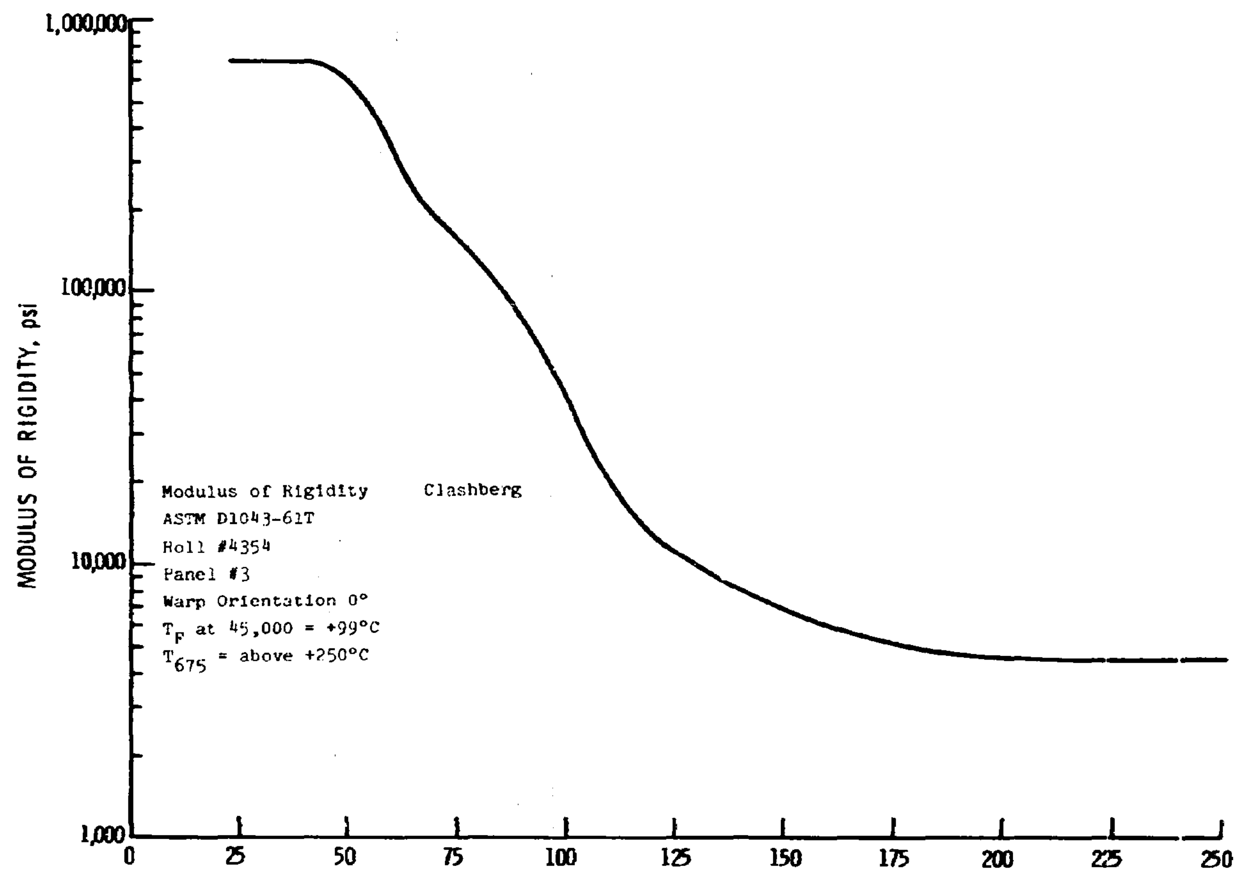

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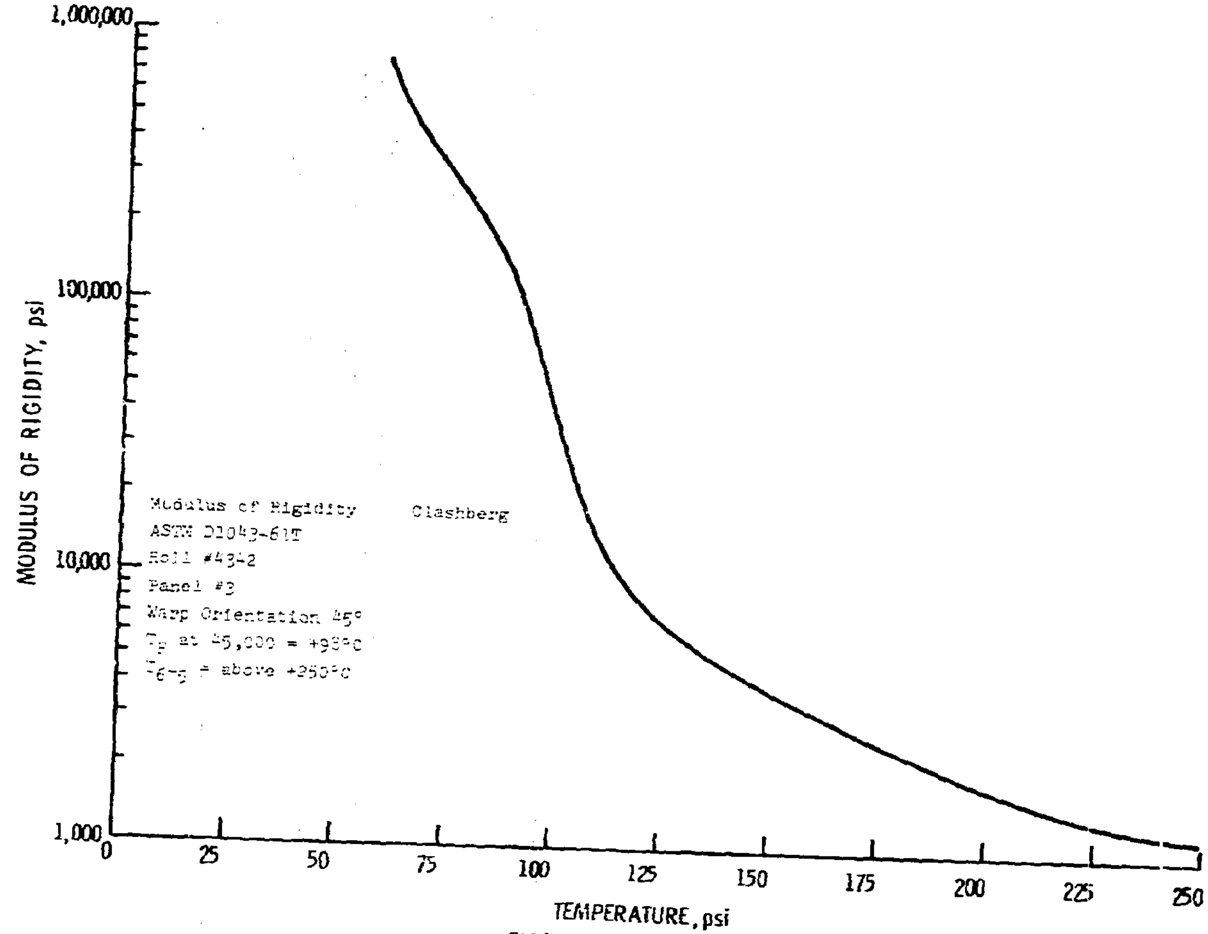

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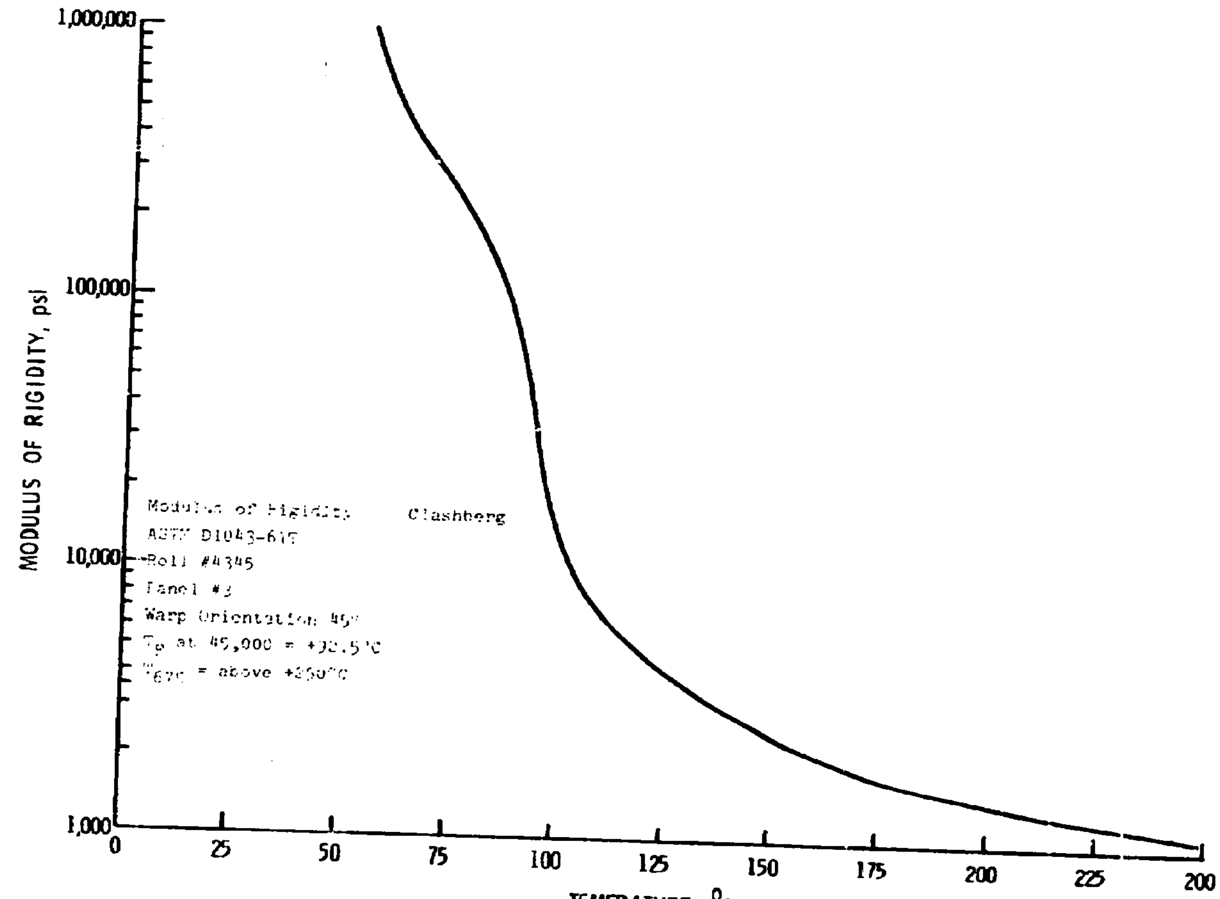

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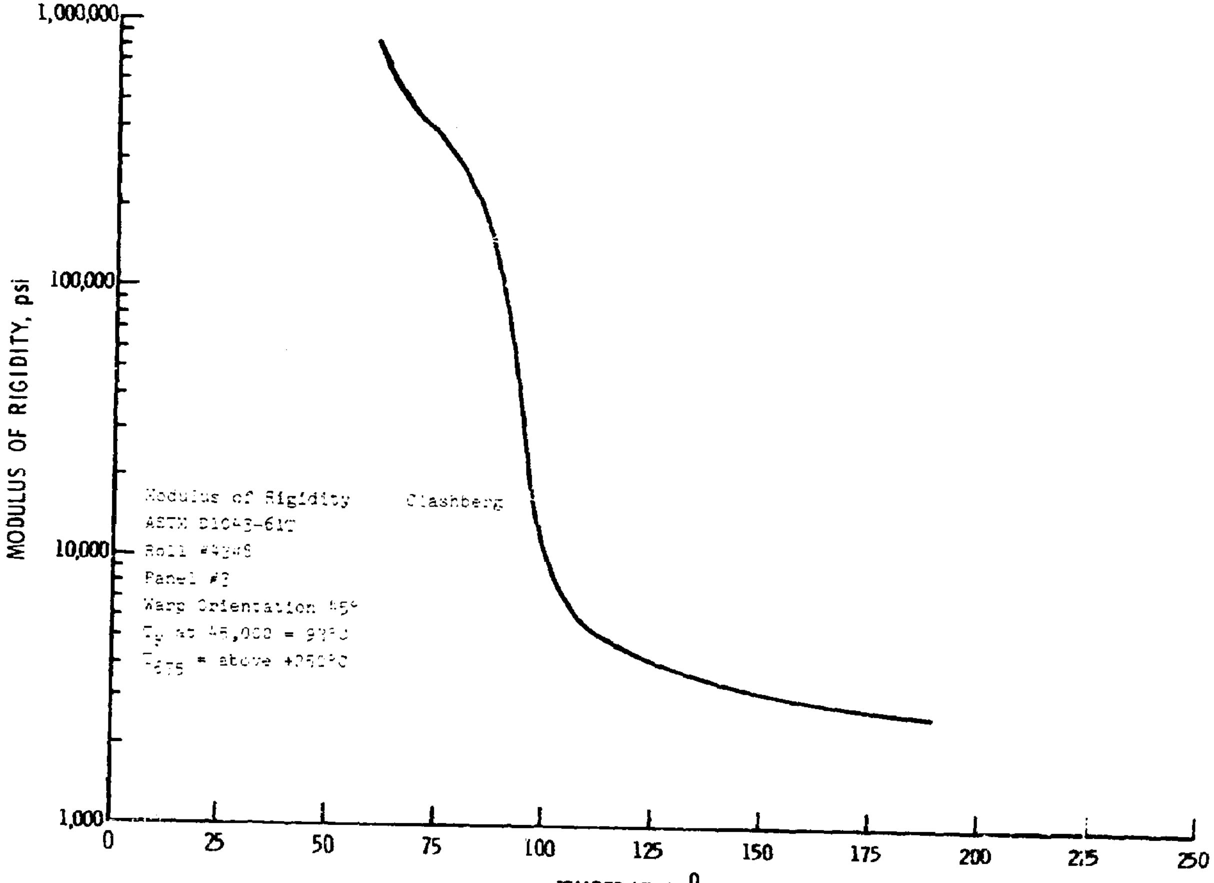

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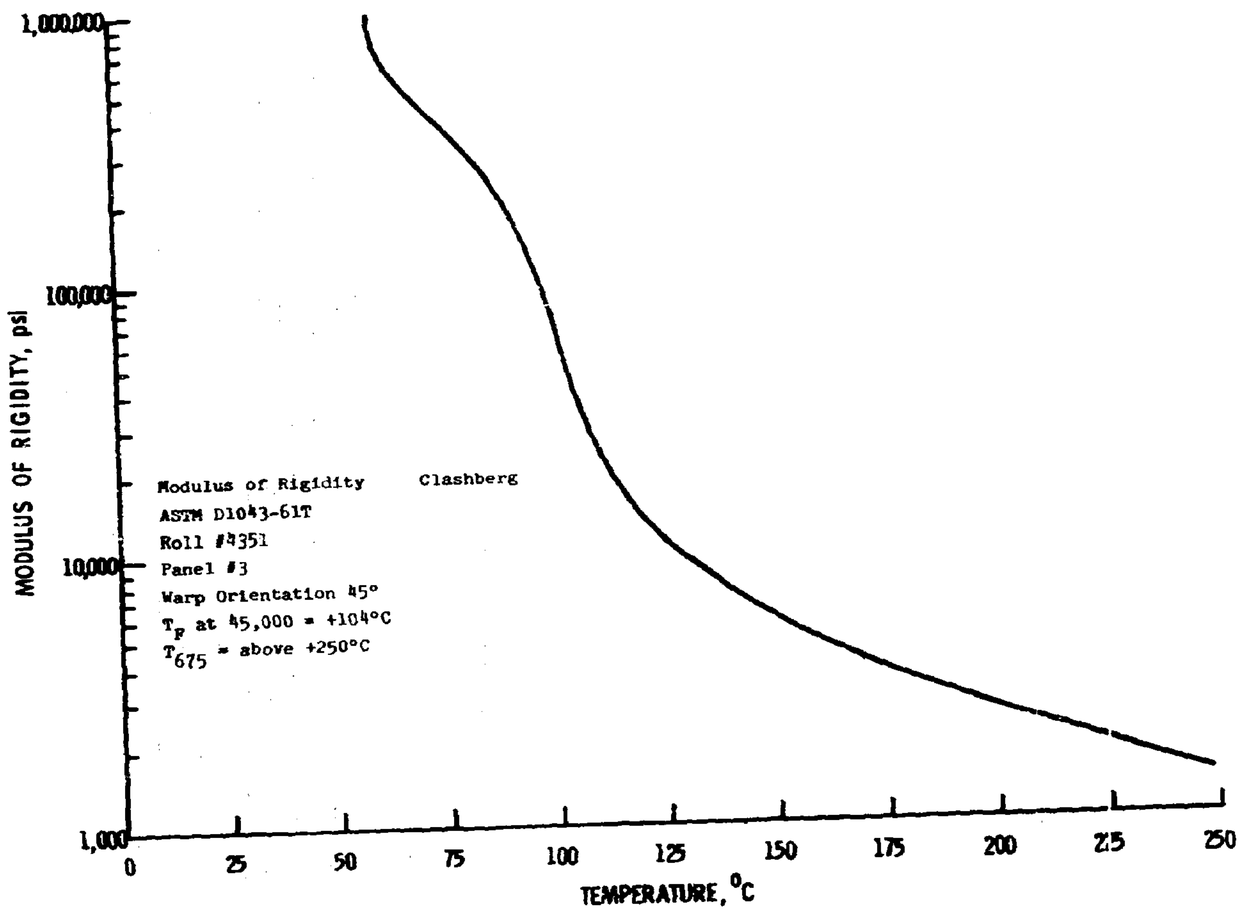

TABLE X CONTINUED

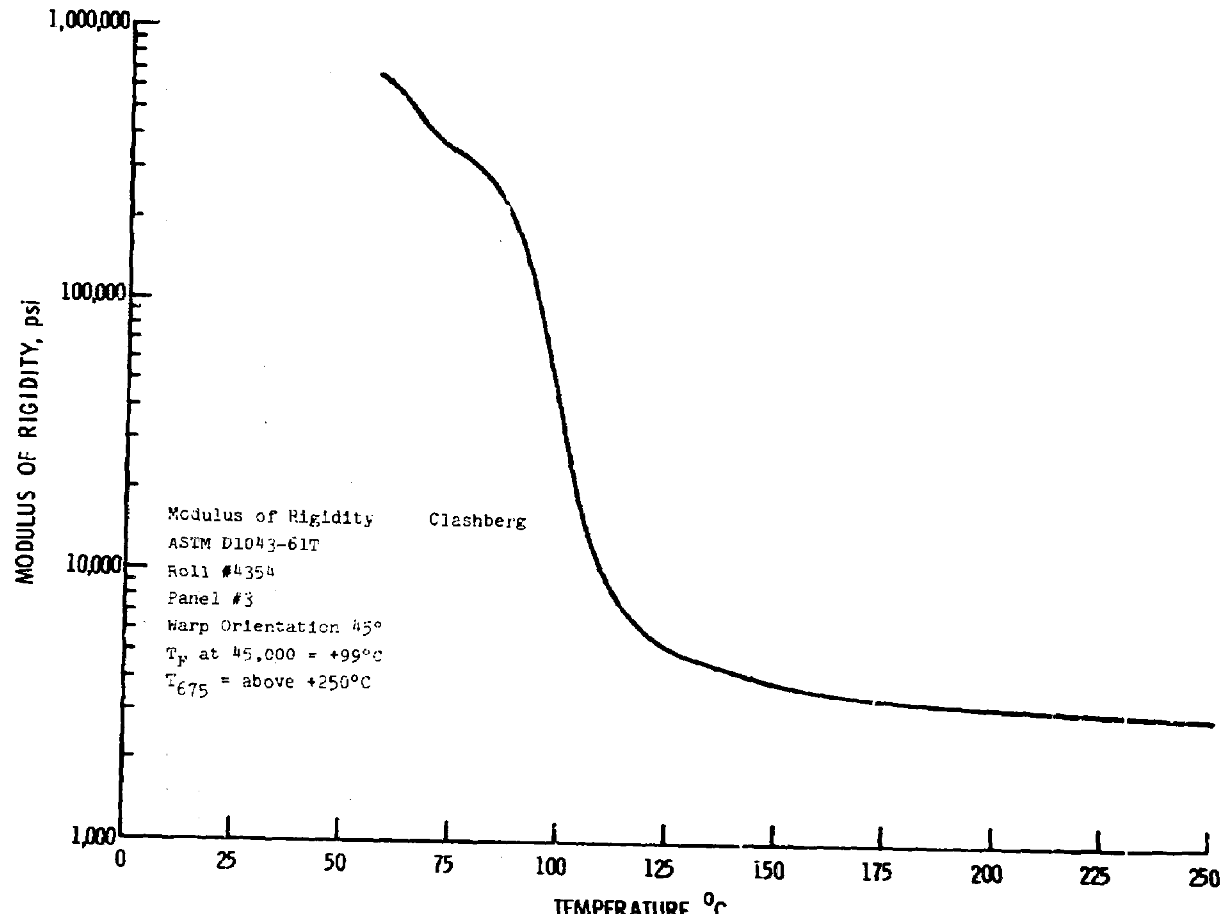

TABLE X CONTINUED

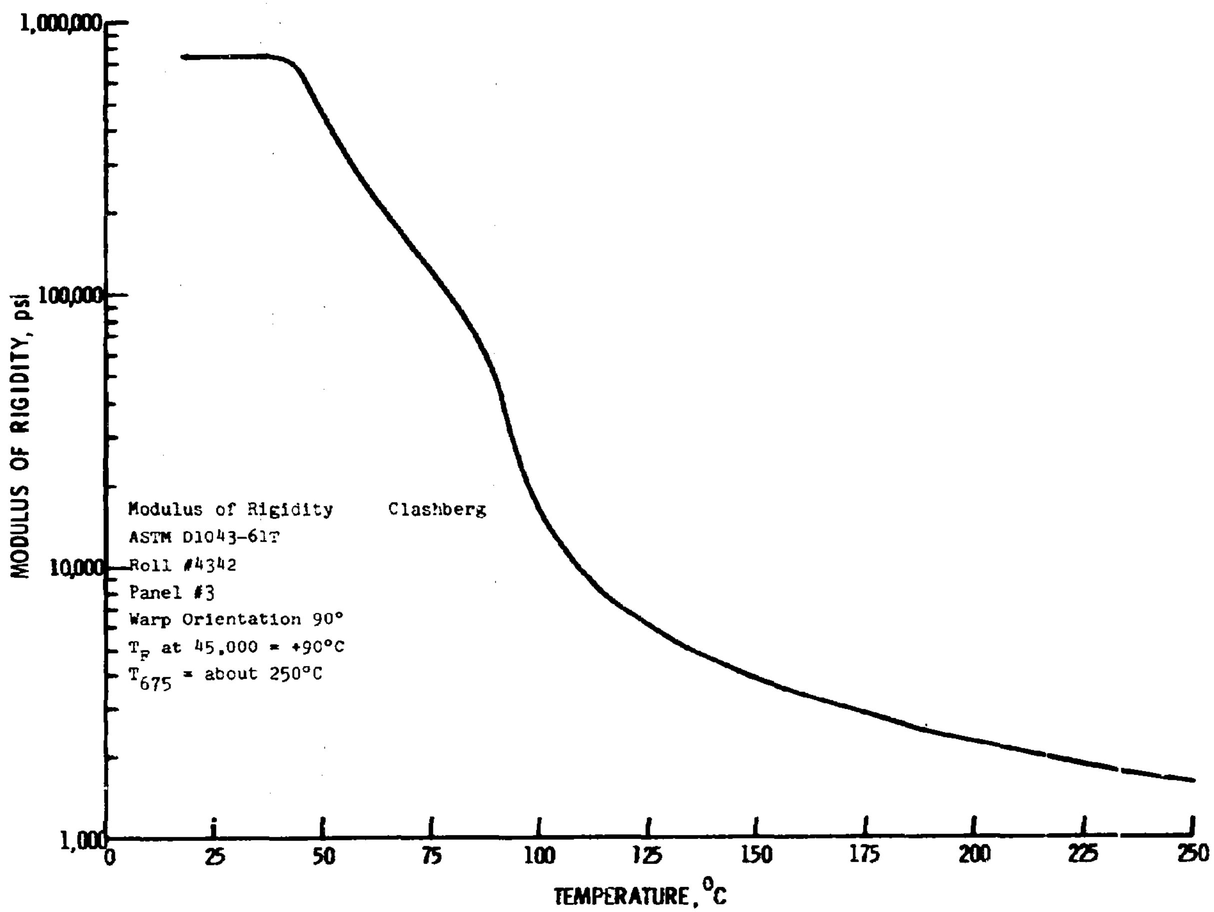

TABLE X CONTINUED

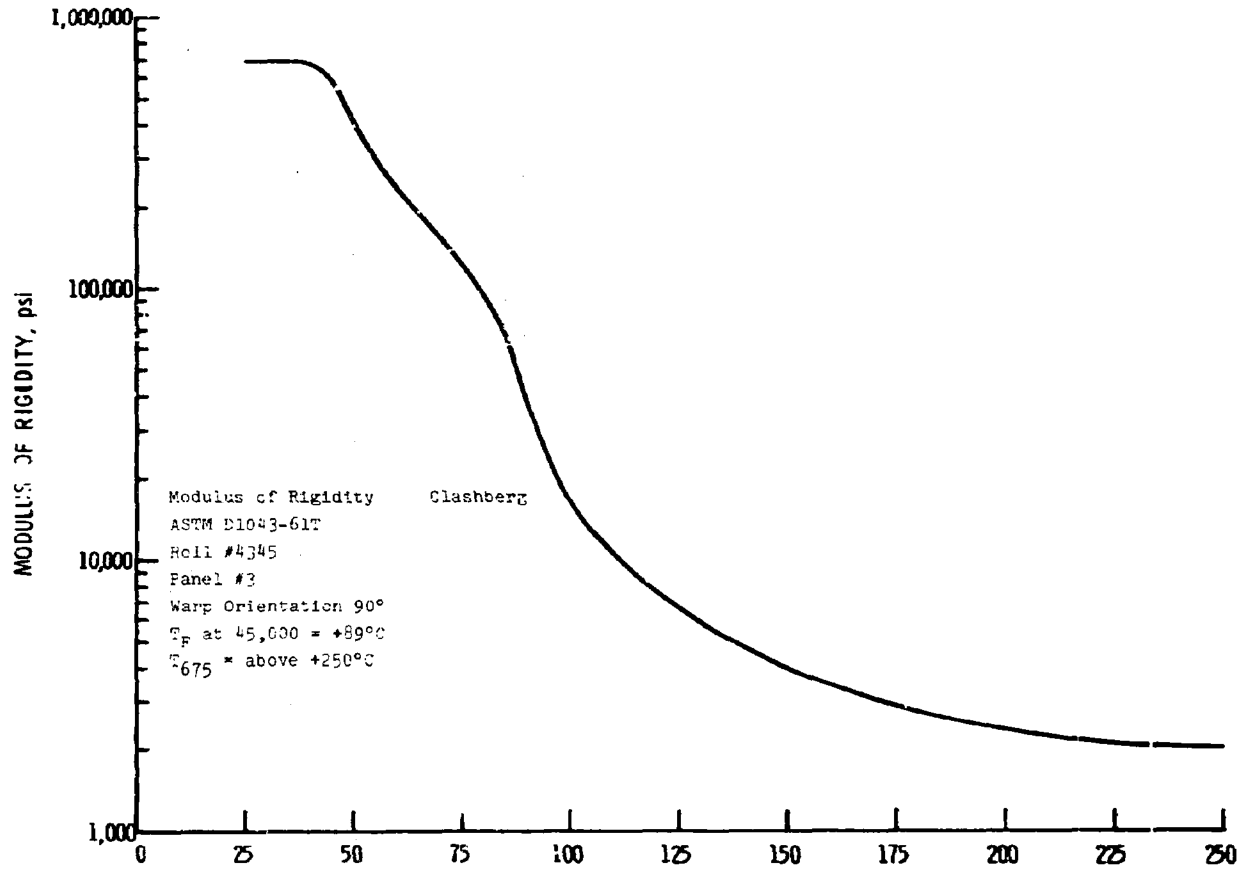

TABLE X CONTINUED

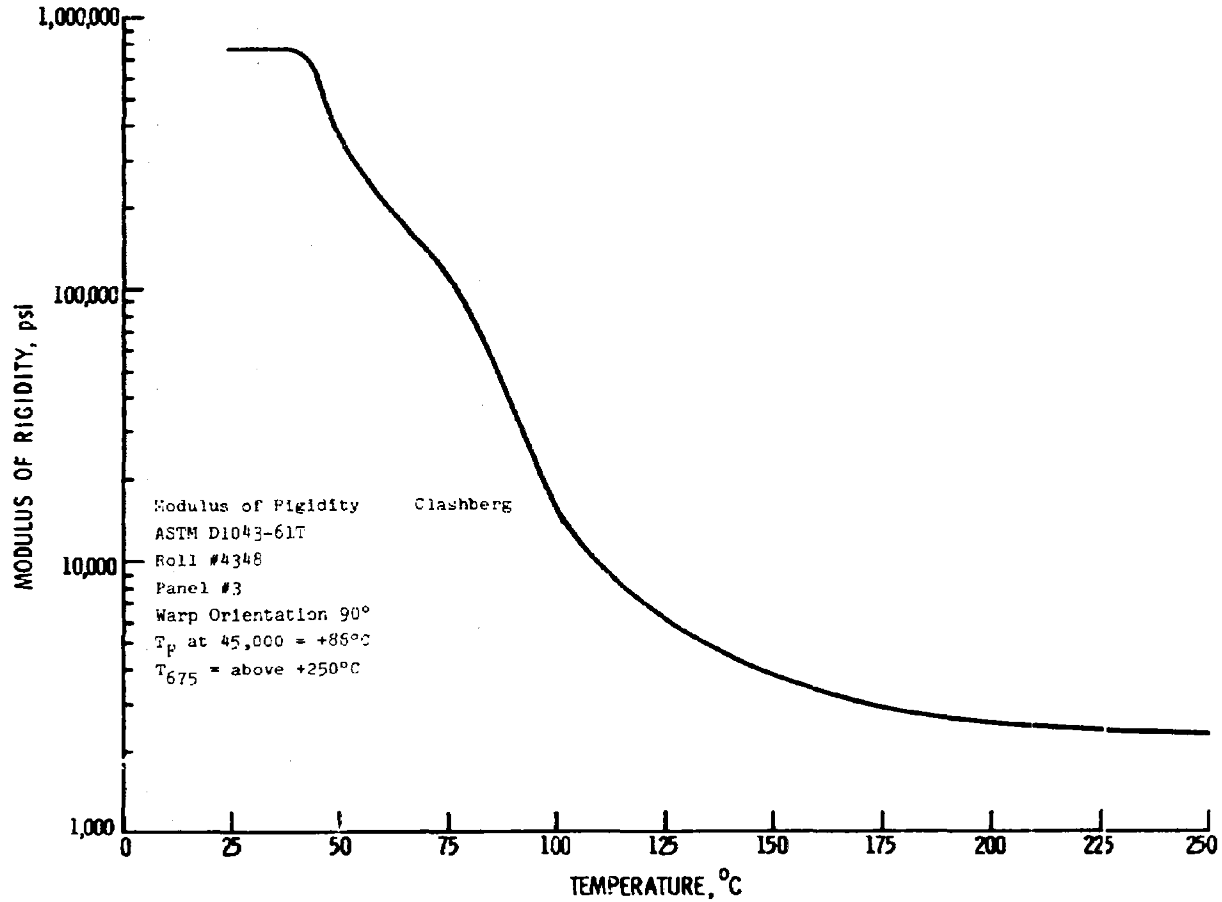

TABLE X CONTINUED

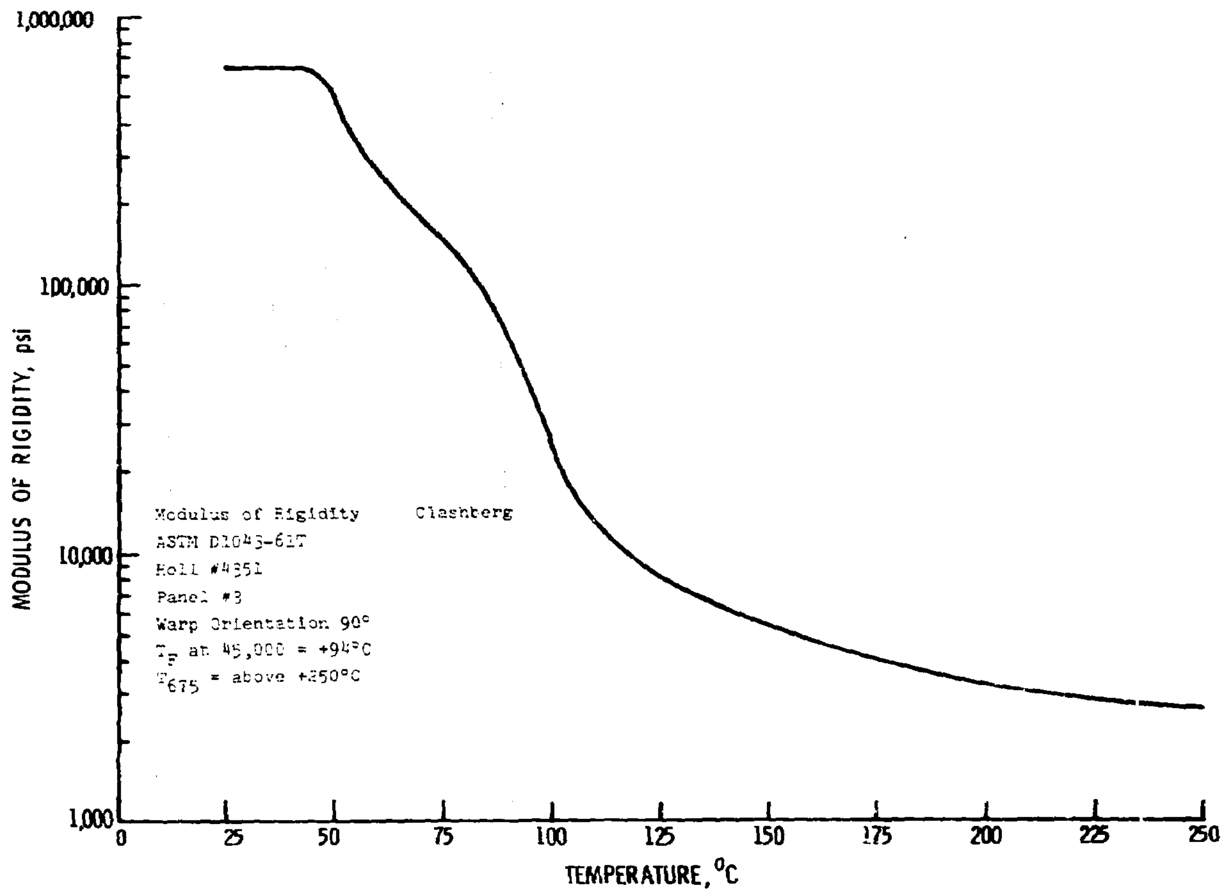

TABLE X CONTINUED

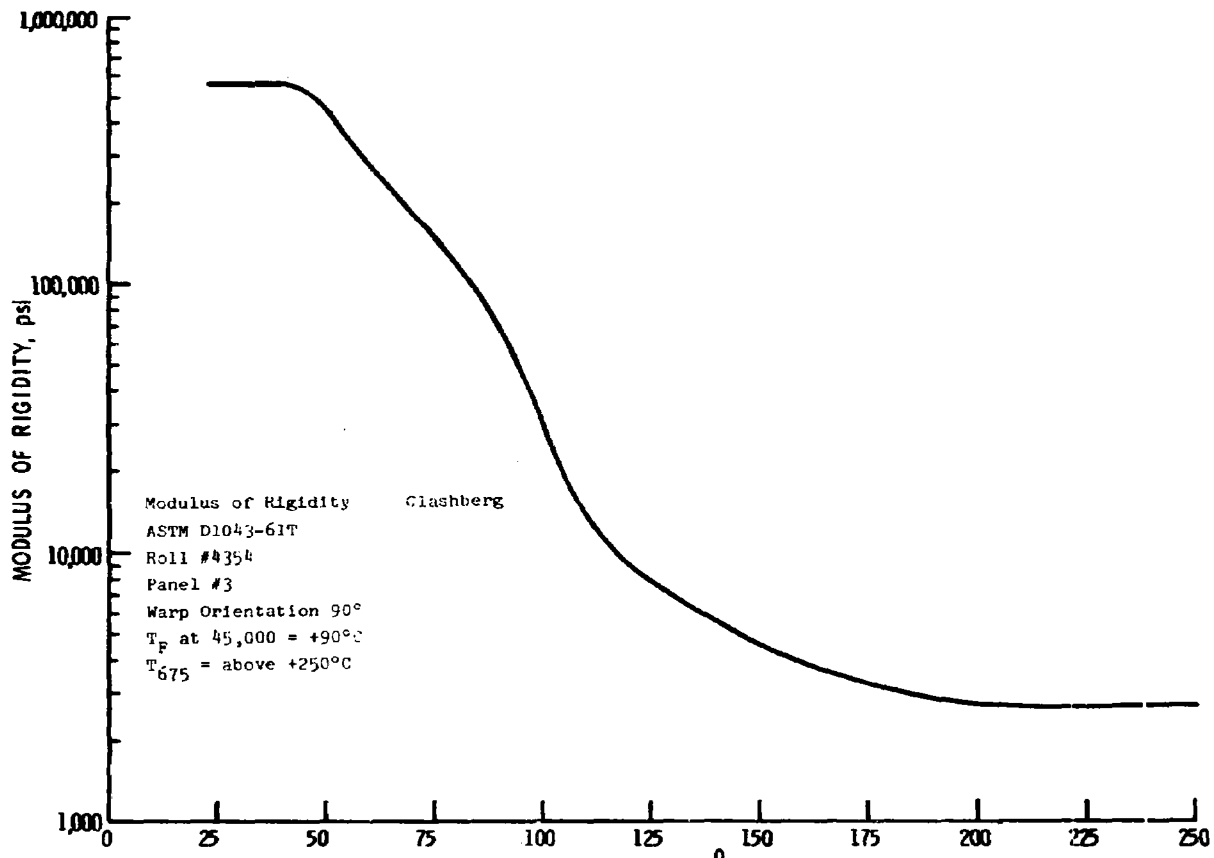

TABLE X CONTINUED

TABLE XI

PHYSICAL PROPERTY TEST

PARTS CURED AT 325°F FOR 3 HOURS AT 30 PSI POST CURED AT 400°F FOR 4 HOURS

Test	#1	#2	#3	#4	#5	Average
Roll #4348 Panel 5 Specific Gravity	1.70	1.75	1.77	1.72	1.72	1.73
Roll #4348 Panel 5 % Resin Content	31.19	29.84	29.33	30.72	30.57	30.33
Roll #4348 Panel 6 Specific Gravity	1.61	1.64	1.62	1.61	1.64	1.62
Roll #4348 Panel 6 % Resin Content	34.21	33.90	33.76	34.19	34.96	34.20
Tensile-0°-PSI	48,000	44,000	40,700			44,233
Tensile-45°-PSI	26,760					26,760
Tensile-90°-PSI	45,700	40,000	42,800			42,833
Tensile Modulus 0° PSI x 10^6	2.82	3.38	3.13			3.11
Tensile ~~Modulus~~ 45° PSI x 10^6	1.57					1.57
Tensile Modulus 90° PSI x 10^6	3.05	2.86	3.05			2.98
Tensile % Elongation 0°	1.7	1.4	1.5			1.53
Tensile % Elongation 45°	7.7					7.7
Tensile % Elongation 90°	1.0	1.6				1.3
Flexural-0° PSI	66,800	50,500	40,600			52,633
Flexural-45° PSI	25,500	24,500	25,500			25,166
Flexural-90° PSI	58,500	60,800	61,100			60,133
Flexural Modulus 0° PSI x 10^6	2.8	3.1	2.8			2.9
Flexural Modulus 45° PSI x 10^6	1.6	1.6	1.6			1.6
Flexural Modulus 90° PSI x 10^6	2.9	3.2	3.0			3.03

TABLE XII

PHYSICAL PROPERTY TEST

AFTER CURE CYCLE 1 HR AT 250°F AT 20 PSI AND 4 HR AT 400°F AT 30 PSI

Specimen #	4345-1	4346-2	4345-3	4345-4	4345-5	Average
Resin Content	30.37	31.08	31.09	31.36	30.35	30.85
Specific Gravity	1.72	1.72	1.73	1.72	1.75	1.73
Tensile PSI	46,500	44,700	46,500			45,900
Tensile Modulus x 10^6 PSI	2.90	2.97	2.90			2.92
Elongation %	1.8	1.7	1.9			1.8
Compression PSI	57,500	47,500	56,200			53,733
Compression Modulus x 10^6 PSI	2.32	2.29	2.36			2.32
Flexural PSI	69,800	75,100	72,300			72,133
Flexural Modulus 10^6 PSI	3.1	3.2	3.1			3.13
Interlaminator Shear	3,800	3,750	2,730			3,426
Bearing	8,690	7,980	8,000			8,223

Table XIII - Compression Modulus and Ultimate Compression Stress

325°F, 30 PSI, 1 1/2 Hours Cure Time				
Spec. No.	Load lbs.	Compression psi	Ult.Compression psi	Comp. Modulus psi
1	3,810	25,940	49,416	3.44×10^6
2	3,760	25,906	48,704	3.61×10^6
3	4,100	25,873	53,040	3.47×10^6
Average →		25,906	50,386	3.50×10^6
425°F, 15 PSI, 1 1/2 Hours Cure Time				
Spec. No.	Load lbs.	Compression psi	Ult.Compression psi	Comp. Modulus psi
1	3,576	29,629	52,962	3.88×10^6
2	3,760	29,806	56,035	3.93×10^6
3	3,600	29,850	53,731	4.78×10^6
Average →		29,762	54,242	4.19×10^6

Table XIV - Bearing Strength of Tank Material

Spec. No.	Hole Diam.	Load lbs.	Bearing Stress psi	Load lbs.	Max. Bearing Stress psi
1	.126	350	28,058	957	76,719
2	.126	430	34,471	910	72,952
3	.126	*		970	77,761
4	.126	320	25,653	1,060	84,976
5	.126	300	24,050	987	79,124
Average →		(4%)	28,057	(Max.)	78,306

* Bad Curve

Table XV Tank Shell Weight Trade-off Studies

WITH BULKHEADS @ 34 INCHES					
Case	F.S.	Shell lbs.	% of Shell	Tank lbs.	% of Tank
I	1.25	64.52	111.24	146.52	104.66
I	1.50	67.25	115.95	149.25	106.61
II	1.25	70.95	122.33	152.95	109.25
II	1.50	75.95	130.95	157.95	112.82

WITHOUT BULKHEADS					
Case	F.S.	Shell lbs.	% of Shell	Tank lbs.	% of Tank
I	1.25	90.41	155.88	172.41	123.15
I	1.50	96.17	165.81	178.17	127.26
II	1.25	103.00	177.59	185.00	132.14
II	1.50	109.31	188.47	191.31	136.65

TABLE XVI
STRESS ANALYSIS OF THE TANK WITHOUT FRAMES

TANK STA. in.	R in.	t in.	Rt $in.^2$	Z_L	k_p	k_t	$F_{P_{CR}}$ psi	$F_{ST_{CR}}$ psi	$F_{S_{CR}}$ psi	$F_{B_{CR}}$ psi	M_B in-kips	M_x in-k	V_R kips	f_P psi	f_{ST} psi	f_S psi	f_B psi	R_P	R_{ST}	R_S	R_B	[illegible]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
10	4.035	.15	.5043	16385	130	1200	287	2650	4240	18268	26000	0	200	242	0	105	391	.84	0	.02	.02	.16
15	5.313	.17	.9032	10963	108	880	306	2496	3994	15723	38000	0	700	281	0	176	497	.92	0	.04	.03	.05
20	6.397	.20	1.2794	7739	90	690	353	2709	4334	15363	48000	0	950	288	0	211	467	.91	0	.05	.03	.18
25	7.330	.21	1.5393	6432	82	590	355	2554	4086	14078	49000	0	1200	314	0	248	465	.89	0	.06	.03	.08
30	8.136	.23	1.8713	5291	75	500	389	2596	4154	13892	72000	3100	1800	318	32	255	481	.82	.01	.06	.03	.16
35	8.828	.24	2.1187	4673	70	460	396	2601	4161	13359	89000	3250	2100	331	28	300	570	.84	.01	.07	.04	.13
40	9.418	.25	2.3545	4205	66	420	405	2577	4122	13044	105000	3400	2500	339	24	331	639	.84	.01	.05	.05	.12
45	9.913	.26	2.5774	3842	64	400	425	2654	4246	12889	122000	3550	2900	343	22	364	691	.81	.01	.09	.05	.15
50	10.317	.27	2.7856	3555	61	370	436	2647	4236	12860	139000	3800	3300	344	21	389	753	.73	.01	.09	.06	.17
55	10.633	.27	2.8709	3449	60	365	429	2612	4179	12478	150000	4250	3650	354	22	399	907	.83	.01	.10	.07	.10
60	10.861	.28	3.0411	3256	59	350	454	2770	4432	12668	163000	4800	4000	349	23	398	1012	.77	.01	.09	.08	.16
65	11.000	.28	3.0800	3215	58	350	446	2693	4309	12508	175000	5350	4200	354	24	424	1165	.79	.01	.10	.09	.11
70	11.000	.29	3.1900	3104	56	340	462	2807	4491	12955	183000	3500	12500	341	15	1282	1279	.74	.01	.29	.10	.08
75	11.000	.29	3.1900	3104	56	340	462	2807	4491	12955	191000	4000	11000	341	18	1153	1406	.74	.01	.26	.11	.08
80	11.000	.29	3.1900	3104	56	340	462	2807	4491	12955	198000	4700	9500	341	20	1038	1542	.74	.01	.23	.12	.09
85	11.000	.29	3.1900	3104	56	340	462	2807	4491	12955	200000	5000	8000	341	33	928	1633	.74	.01	.21	.13	.09

$E = 1.17 \times 10^6$, $\nu = .14$, $L = 100$ in.

TABLE XVII
STRESS ANALYSIS OF THE TANK WITH L 20 INCHES

TANK STA. in.	R in.	t in.	Rt $in.^2$	Z_L	k_p	k_t	$F_{P_{CR}}$ psi	$F_{ST_{CR}}$ psi	$F_{S_{CR}}$ psi	$F_{B_{CR}}$ psi	M_B in-kips	M_x in-k	V_R kips	f_P psi	f_{ST} psi	f_S psi	f_B psi	R_P	R_{ST}	R_S	R_B	M.S.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
10	4.035	.06	.2421	1636	46	245	853	4545	7272	15345	26000	0	200	605	0	263	978	.71	0	.04	.06	.29
15	5.313	.07	.3719	1065	34	154	858	3888	6222	13586	38000	0	700	683	0	428	1208	.80	0	.07	.09	.12
20	6.397	.08	.5118	774	29	120	956	3958	6332	12905	48000	0	950	720	0	529	1167	.75	0	.08	.09	.17
25	7.330	.08	.5864	675	28	110	923	3628	5804	11253	48000	0	1200	825	0	651	1222	.65	0	.11	.11	.00
30	8.136	.09	.7322	541	24	93	1002	3882	6211	11415	72000	3100	1800	814	33	652	1229	.81	.02	.10	.11	.07
35	8.828	.10	.8828	449	22	80	1134	4122	6596	11689	85000	3250	2100	795	66	721	1368	.70	.02	.11	.12	.20
40	9.418	.10	.9418	421	22	76	1134	3916	6266	10957	101000	3400	2500	848	61	828	1597	.73	.02	.13	.15	.09
45	9.913	.10	.9913	400	21	74	1108	3813	6101	10410	120000	3550	2900	892	58	947	1798	.81	.02	.16	.17	.00
50	10.317	.11	1.1349	349	20	65	1247	4115	6584	11003	139000	3800	3300	844	52	954	1849	.63	.02	.14	.17	.15
55	10.633	.11	1.1696	339	19	64	1185	3990	6385	10676	150000	4250	3650	870	55	979	2227	.73	.01	.15	.21	.03
60	10.851	.11	1.1947	332	19	63	1185	3928	6285	10451	162000	4800	4000	889	59	1012	2576	.75	.01	.16	.25	-.03
65	11.000	.12	1.3200	300	18	60	1336	4452	7124	11258	175000	5350	4200	825	57	989	2718	.62	.01	.14	.24	.13
70	11.000	.13	1.4300	277	17	56	1480	4877	7803	12196	183000	3500	12500	762	33	2860	2853	.51	.01	.37	.23	.11
75	11.000	.13	1.4300	277	17	56	1480	4877	7803	12196	191000	4000	11000	762	39	2571	3137	.51	.01	.33	.26	.11
80	11.000	.13	1.4300	277	17	56	1480	4877	7803	12196	198000	4700	9500	762	46	2315	3440	.52	.01	.30	.28	.11
85	11.000	.13	1.4300	277	17	56	1480	4877	7803	12196	200000	5000	8000	762	74	2070	3642	.51	.02	.27	.30	.11

$E = 2.457 \times 10^6$ psi, $\nu = .14$, L = 20 in.

TABLE XVIII
STRESS ANALYSIS OF THE TANK WITH L 100 INCHES

TANK STA. in.	R in.	t in.	Rt in^2	Z_L	k_p	k_t	$F_{P_{CR}}$ psi	$F_{ST_{CR}}$ psi	$F_{S_{CR}}$ psi	$F_{B_{CR}}$ psi	M_B in-kips	M_x in-k	V_R kips	f_P psi	f_{ST} psi	f_S psi	f_B psi	R_P	R_{ST}	F_S	R_B	M.S.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
10	4.035	.11	.4439	22308	152	1500	379	3741	5985	28132	26000	0	200	330	0	143	533	.87	0	.02	.02	.12
15	5.313	.13	.6907	14336	123	1080	428	3762	6019	25250	38000	0	700	368	0	230	651	.86	0	.04	.03	.13
20	6.397	.14	.8956	11066	109	880	440	3555	5688	22584	48000	0	950	411	0	302	667	.93	0	.05	.03	.03
25	7.330	.15	1.0995	9005	98	765	454	3548	5677	21117	48000	0	1200	440	0	347	652	.97	0	.06	.03	.00
30	8.136	.16	1.3018	7606	91	665	480	3509	5614	20294	72000	3100	1800	458	47	367	691	.95	.01	.07	.03	.01
35	8.828	.17	1.5008	6598	83	600	494	3574	5719	19872	89000	3250	2100	467	39	424	805	.95	.01	.07	.04	.01
40	9.416	.18	1.6952	[illegible]	80	550	534	3673	5877	19723	105000	3400	2500	471	34	460	887	.85	.01	.08	.04	.07
45	9.913	.18	1.7843	[illegible]	77	530	514	3539	5663	18738	122000	3550	2900	496	32	526	999	.95	.01	.09	.05	.00
50	10.317	.15	1.9602	5051	73	490	543	3646	5834	19004	139000	3500	3300	489	30	552	1070	.90	.01	.03	.06	.03
55	10.633	.19	2.0203	[illegible]	72	480	536	3572	5715	18440	150000	4250	3650	504	32	567	1289	.93	.01	.10	.06	.01
60	10.861	.20	2.1722	4553	71	450	585	3710	5936	19003	162000	4800	4000	489	32	557	1417	.83	.01	.09	.07	.09
65	11.000	.20	2.2000	4501	70	445	577	3669	5870	18763	175000	5350	4200	495	34	593	1631	.86	.01	.10	.09	.04
70	11.000	.21	2.3200	4286	68	430	618	3909	6254	19701	183000	3500	12500	471	21	1771	1766	.76	.01	.28	.09	.06
75	11.000	.21	2.3200	4286	68	430	618	3909	6254	19701	191000	4000	11000	471	24	1592	1942	.76	.01	.25	.10	.07
80	11.000	.21	2.3200	4286	68	430	618	3909	6254	19701	198000	4700	9500	471	28	1433	2130	.76	.01	.23	.11	.07
85	11.000	.21	2.3200	4286	68	430	618	3909	6254	19701	200000	[illegible]	8000	471	46	1282	2255	.76	.01	.20	.11	.08

$E = 2.457 \times 10^6$ psi, $\nu = .14$, $L = 100$ in.

TABLE XIX
FINAL STRESS ANALYSIS OF THE TANK L 34 INCHES

TANK STA. in.	R in.	t in.	Rt $in.^2$	Z_L	k_p	k_t	$F_{P_{CR}}$ psi	$F_{ST_{CR}}$ psi	$F_{S_{CR}}$ psi	$F_{B_{CR}}$ psi	M_B in-kips	M_x in-k	V_R kips	f_P psi	f_{ST} psi	f_S psi	f_B psi	R_P	R_{ST}	R_S	R_B	M.S.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
10	4.035	.06	.2421	4728	71	473	471	3139	5022	15863	26000	0	200	404	0	263	978	.86	0	.05	.06	.09
15	5.313	.07	.3719	3078	58	340	524	3071	4913	14055	38000	0	700	455	0	428	1208	.87	0	.09	.09	[illegible]
20	6.397	.08	.5118	2237	50	270	590	3185	5096	13341	48000	0	950	480	0	529	1167	.81	0	.10	.09	.10
25	7.330	.09	.6597	1832	44	225	657	3359	5375	13099	48000	0	1200	489	0	579	1096	.74	0	.11	.08	.19
30	8.136	.09	.7322	1563	42	207	627	3091	4945	11801	72000	3100	1800	542	83	652	1229	.86	.05	.13	.10	.01
35	8.828	.10	.8828	1297	38	180	700	3318	5309	12084	89000	3250	2100	539	66	721	1368	.76	.02	.14	.11	.12
40	9.418	.10	.9418	1215	36	170	664	3134	5014	11327	105000	3400	2500	565	61	828	1597	.85	.02	.17	.14	-.03
45	9.913	.11	1.0904	1050	34	155	758	3457	5531	11838	122000	3550	2900	541	53	861	1634	.71	.02	.16	.14	.13
50	10.317	.11	1.1349	1009	33	148	736	3301	5282	11374	139000	3800	3300	563	52	954	1849	.76	.02	.18	.16	.03
55	10.633	.12	1.2760	939	32	134	849	3557	5691	12040	150000	4250	3650	532	50	898	2041	.63	.01	.16	.17	.20
60	10.861	.12	1.3033	878	31	131	823	3477	5563	11787	162000	4800	4000	543	54	928	2361	.66	.02	.17	.20	.11
65	11.000	.12	1.3200	867	30	130	796	3451	5521	11638	175000	5350	4200	550	57	989	2718	.69	.02	.18	.23	.04
70	11.000	.14	1.5400	743	28	118	1012	4263	6821	13557	183000	3500	12500	471	31	2656	2649	.47	.01	.39	.20	.14
75	11.000	.14	1.5400	743	28	118	1012	4263	6821	13557	191000	4000	11000	471	37	2387	2913	.47	.01	.35	.21	.20
80	11.000	.14	1.5400	743	28	118	1012	4263	6821	13557	198000	4700	9500	471	42	2150	3194	.47	.01	.32	.24	.21
85	11.000	.14	1.5400	743	28	118	1012	4263	6821	13557	200000	5000	8000	471	69	1922	3382	.47	.02	.28	.25	.22

$E = 2.457 \times 10^6$ psi, $\nu = .14$, $L = 34$ in.

Table XX Basic Dimensions of the Tank

TANK STATION	RADIUS	SLOPE	TANK STATION	TANK STATION	RADIUS	SLOPE	TANK STATION
5.0	2.4675	.3580	161.0	36.0	8.9538	.1238	130.0
6.0	2.8143	.3365	160.0	37.0	9.0756	.1198	129.0
7.0	3.1417	.3188	159.0	38.0	9.1934	.1159	128.0
8.0	3.4529	.3038	158.0	39.0	9.3073	.1120	127.0
9.0	3.7501	.2908	157.0	40.0	9.4174	.1082	126.0
10.0	4.0350	.2793	156.0	41.0	9.5238	.1045	125.0
11.0	4.3090	.2689	155.0	42.0	9.6264	.1009	124.0
12.0	4.5730	.2593	154.0	43.0	9.7255	.0973	123.0
13.0	4.8279	.2505	153.0	44.0	9.8210	.0937	122.0
14.0	5.0743	.2423	152.0	45.0	9.9130	.0903	121.0
15.0	5.3127	.2345	151.0	46.0	10.0013	.0864	120.0
16.0	5.5435	.2272	150.0	47.0	10.0858	.0826	119.0
17.0	5.7671	.2201	149.0	48.0	10.1665	.0789	118.0
18.0	5.9837	.2132	148.0	49.0	10.2436	.0753	117.0
19.0	6.1937	.2066	147.0	50.0	10.3172	.0718	116.0
20.0	6.3970	.2001	146.0	51.0	10.3872	.0683	115.0
21.0	6.5943	.1945	145.0	52.0	10.4538	.0649	114.0
22.0	6.7861	.1891	144.0	53.0	10.5170	.0614	113.0
23.0	6.9725	.1837	143.0	54.0	10.5767	.0580	112.0
24.0	7.1536	.1785	142.0	55.0	10.6330	.0545	111.0
25.0	7.3295	.1734	141.0	56.0	10.6858	.0510	110.0
26.0	7.5004	.1684	140.0	57.0	10.7351	.0475	109.0
27.0	7.6664	.1635	139.0	58.0	10.7807	.0438	108.0
28.0	7.8275	.1587	138.0	59.0	10.8227	.0401	107.0
29.0	7.9839	.1540	137.0	60.0	10.8609	.0362	106.0
30.0	8.1356	.1495	136.0	61.0	10.8952	.0322	105.0
31.0	8.2828	.1450	135.0	62.0	10.9253	.0280	104.0
32.0	8.4256	.1406	134.0	63.0	10.9512	.0236	103.0
33.0	8.5640	.1362	133.0	64.0	10.9724	.0189	102.0
34.0	8.6981	.1320	132.0	65.0	10.9888	.0139	101.0
35.0	8.8280	.1278	131.0	66.0*	11.0000	.0084	100.0*

* Cylindrical between Stations 66.0 and 100.0 with R 11.0000 in.

APPENDIX III

WING TANK MATERIAL SPECIFICATION
MATERIAL CLOTH

No MRC-MS-001
REVISION "A" 12-4-67

1. Scope

1.1 This specification establishes the requirements to be met for B-staged epoxy resin impregnated glass fabric

1.2 Classification

1.2.1 Types - The material is available in the following types:

Types I - 181 style E- glass fabric constructed from yarns designated as ECDE 75-1/0 impregnated with an epoxy resin (See 3.4 and 3.5)

2. Applicable Documents

2.1 The following documents, of the issue in effect on date of initiation for bid or request for proposal, form a part of this specification to the extent specified herein:

Specifications

Federal	L-P-378	Plastic film (polyethylene thin gage)
Military	MIL-F-9118	Finish, for glass fabric
	MIL-R-9300	resin, epoxy, low pressure laminating

Standards

Federal

Fed Test Method Std No. 406	Plastics: Methods of Testing

NOTE: The information presented on this page is proprietary and shall not be disclosed without consent of Monsanto Research Corporation.

3. Requirements

3.1 Qualification - The impregnated cloths furnished under this specification shall be a product which has been tested, and passed the qualification tests specified herein, and has been listed on or approved for listing on the applicable list.

3.2 Materials

3.2.1 Sizes Available - The material shall be supplied as broad goods of the type listed in 1.2.1, and shall conform to the following requirements.

A 3.2.1.1 Impregnated Fabric - Fabric shall be supplied as yardage 38.0 ± 2.0 inches wide, with a minimum roll length of 35 yards and a maximum roll length of 75 yards. There shall be no more than two separate lengths of fabric per roll, and neither shall be less than 20 yards in length. The minimum roll length requirement shall not apply when the order weight limitation prevents conformance. However, in no case shall there be more than 75 yards in one roll.

3.3 Finish

3.3.1 The glass fabric prior to impregnation shall be treated with Volan "A" finish in accordance with MIL-F-9118.

A 3.4 Resin Formulation:

	Solids % By Weight	Mix % By Weight
Epon 828	37.22	37.22
DICY (Dicyandiamide)	1.11	1.11
Butvar B76*	12.41	12.41
Thermolite #31 **	.37	.37
Acetone		42.39
DMF (Dimethylformamide)		6.00
Deionized H_2O		.50
TOTAL	51.11	100.00

3.5 Properties of the Uncured Preimpregnated Fabric:

Resin solids content (dry) 38 ± 2%
Volatile content Less than 1%
Resin flow 14 ± 3%
Gel time (minutes) 4 to 9

NOTE: The information presented on this page is proprietary and shall not be disclosed without consent of Monsanto Research Corporation.

3.6 Storage Stability - The impregnated fabric shall meet the reguirements specified herein after storage for three months from date of manufacture at a maximum temperature of 40°F. No material shall be shipped after 30 days from date of manufacture.

3.7 Approval - Material furnished to the requirements of this specification shall be a product that has received approval from the procuring activity, and is listed in 6.4. The supplier is advised that no material formulation or construction can be changed without approval.

3.8 Workmanship - This material shall be free of foreign matter and shall be prepared in accordance with the best commercial practices for this material.

4. Quality Assurance Provisions

4.1 Responsibility for Inspections - Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any commercial laboratory acceptable to the procuring activity. The procuring activity reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Qualification Tests - Qualification tests for the material supplied under this specification shall consist of those tests necessary to show conformance with all the requirements of this specification.

4.3 Acceptance Inspections - Acceptance inspections shall consist of the following tests:

a. Resin solids content
b. Volatile content
c. Resin flow
d. Gel time
e. Tensile strength (ambient temperature)
f. Flexural strength (ambient temperature)
g. Identification

4.3.1 Acceptance Test Report - The supplier shall include with each lot shipped, two copies of a written test report stating test results conforming to all the acceptance inspection tests specified in 4.3.

NOTE: The information presented on this page is proprietary and shall not be disclosed without consent of Monsanto Research Corporation.

4.4 Test Methods

4.4.1 Volatile Content - Using a template, cut four (4 x 4 inches) square specimens on the bias from random locations on each sample. Weigh each specimen to the nearest milligram (0.001 g) and then suspend each in a circulating air oven at 325 ± 5°F for 15 minutes ± 1 minute. On removing the specimens from the oven, cool in a desiccator to room temperature and reweigh each specimen to the nearest milligram. The average of the four values shall be recorded. Calculate the volatile content as follows:

$$\text{Volatile content, weight percent} = \frac{W_o - W_1}{W_o} \times 100$$

where: W_o = original weight (in grams)

W_1 = weight of specimen after volatiles removed (in grams)

4.4.2 Resin Solids Content - The four specimens used for the volatile content tests shall be placed in previously ignited, cooled and weighed porcelain evaporating dishes. The specimens shall then be ignited in a muffle furnace maintained at 1050 ± 50°F for a minimum of one hour or until the glass fabric is white in color. Cool the specimens to room temperature in a desiccator and reweigh each specimen to the nearest milligram. Calculate the resin content as follows; and record the average of the four values:

$$\text{Resin Solids content, weight percent} = \frac{W_1 - W_2}{W_1} \times 100$$

where: W_1 = weight of specimen after volatiles removed (in grams)

W_2 = weight of specimen after ignition (in grams)

4.4.3 Wet Resin Flow - Using a template, cut twenty-one (4 by 4 inches) squares on the bias from random locations on each sample. Stack seven of these squares to form a specimen, weigh to the nearest milligram and then place a sheet of .005-inch thick Teflon or other suitable parting film on each side of the specimen. Place the specimen in the center of a preheated press with platen maintained at 325 ± 5°F. Immediately close the press and apply a dead weight pressure of 15 psi. Cure the specimen for 15 minutes minimum, remove the parting film from the specimen. Allow

NOTE: The information presented on this page is proprietary and shall not be disclosed without consent of Monsanto Research Corporation.

to cool to ambient temperature and carefully remove the resin flash. Then reweigh to the nearest milligram. Calculate the resin flow as follows and report the average of the three results:

$$\text{Resin flow percent} = \frac{W_3 - W_4}{W_3} \times 100$$

where: W_3 = original weight of specimen prior to cure

W_4 = weight of specimen after cure with flash removed.

4.4.4 Gel Time - Before fabricating the mechanical test specimens, determine the gelation time of the material as follows:

a. Prepare a laminate using a template to cut a sufficient number of squares (4 by 4 inches). Sandwich this specimen between sheets of tetrafluoroethylene-coated glass cloth or other parting material. The total thickness shall be compatible with the procedure defined in (c) below.

b. Place the specimen in the center of the platens of a preheated press which has been stabilized at 325 ± 5°F and close rapidly applying a pressure of 30 psi.

c. Probe the extruded resin with rigid 1/8-inch diameter wood stick until gelation occurs. Preceding gelation, the resin will adhere to the angled surface of the probe and long strings will form as the probe is withdrawn. Gelation is defined as the time after pressure application at which the resin will no longer form strings. Report the average of two determinations.

4.4.5 Mechanical Test Specimen Preparation

4.4.5.1 Laminate Preparation - Prepare a laminate approximately 10 by 12 inches with the warp direction parallel to the 10-inch dimension A sufficient number of plies shall be used to give a cured thickness of .125 + 0.010 - 0.020 inch. The lay-up shall be placed between a .005-inch Teflon or other suitable release film leaving the ends open. Place the laminate in a preheated press maintained at 325 ± 10°F and apply a pressure of 30 psi

6. Notes

6.1 Intended Use - The material covered by this specification is intended for use in the fabrication of laminated structural components which may be subjected to temperature of 165°F.

6.2 Ordering Date - Procurement documents should specify the following:

a. Title, number and date of this specification

b. Material type required

c. Quantity required in yards

6.3 Definitions

6.3.1 Impregnated Fabric Lot Size - A lot of epoxy resin impregnated fabric shall consist of the original rolls of one lot of fabric and one batch of resin used for impregnation at the same time in one continuous uninterrupted 24-hour coating operation so that the length requirement of 3.2.1.1 shall not consist of material from more than one lot number.

6.3.2 Resin Batch - A resin batch is defined as that quantity of material which has been subjected to unit chemical processing, or physical mixing, or both, designed to produce a product of substantially uniform characteristics.

6.4 Source of Supply:

6.4.1 Cordo Division of Ferro Corporation, P. O. Box 72, Mobile, Alabama 36610

A * Purchased from Monsanto Company
St. Louis, Missouri.

** Purchased from M & T Chemical Company
Rahway, New Jersey.

APPENDIX IV

REVISION-C

REVISED 12-29-67

WING TANK MANUFACTURING PROCESS SPECIFICATION

No. MRC-MP-001

SUBJECT: Pressure bag molding reinforced thermoplastics for making an expandable, rigidizable wing tip tank.

1. Scope

1.1 This process describes and establishes the procedures and requirements for the fabrication of an expandable, rigidizable wing tip tank

1.2 There is no equivalent government process specification.

1.3 Types or Classes

1.3.1 Type I - Fabric, 181-75ECDE yarns "E" glass fabric impregnated, MRC-MS-001 Type I

1.4 Applicable Documents:

The following documents of the issue shown form a part of this specification to the extent specified herein.

1.4.1 Government Specifications and Standards:

Federal test method standards 406-plastics, method of testing

2. Materials

2.1 181 Style E-glass fabric constructed from yarns designated as ECDE 75-1/0 impregnated.

Spec: MRC-MS-001

NOTE: The information presented on this page is proprietary and shall not be disclosed without consent of Monsanto Research Corporation.

Source: Coast Manufacturing & Supply Company
Cordo Division of Ferro Corporation
Narmco Materials Division

2.2 EPON 828 Resin

Source: Shell Chemical Company, Cleveland, Ohio

2.3 Dicyandiamide (DICY)

Source: Matheson Coleman & Bell, Cincinnati, Ohio

2.4 Butvar B-76

Source: Monsanto Company, St. Louis, Missouri

2.5 Thermolite 31

Source: M & T Chemical Incorporated, Cincinnati, Ohio

2.6 Solvent, Dimethylformamide (DMF)

Source: Amsco Solvents & Chemical Company, Cincinnati, Ohio

2.7 Solvent, Acetone

Source: Amsco Solvent & Chemical Company, Cincinnati, Ohio

2.8 Solvent, Naptha

Source: Amsco Solvent & Chemical Company, Cincinnati, Ohio

2.9 Deionized H_2O

2.10 Polyethylene Bag .002" thick

2.11 Capron 80 film .003" thick

Source: Allied Chemical Corporation, Morristown, New Jersey

2.12 Tedlar Film .002" thick

Source: E. I. DuPont De Nemours & Company, Cleveland, Ohio

A2.13 Mold Release, 252-C Solution

Source: Axel Plastics Research Laboratory, Long Island City, New York

A2.14 Nylon Bleeder Fabric Style #3921

Source: Miltex, Incorporated, Fort Washington, New York

NOTE: The information presented on this page is proprietary and shall not be disclosed without consent of Monsanto Research Corporation.

A2.15 Cotton Bleeder Cloth Style Goldtex #80[illegible]

Source: Industrial Textiles, Incorporated, Cincinnati, Ohio

3. Equipment

3.1 Vacuum pump-capable of pulling minimum of 25 inches Hg.

3.2 Pressure pump-capable of pumping air to 45 psi.

3.3 Pressure regulator-capable of controlling pressure $\pm$ 1 psi

3.4 Female Thermo Rubber Bag to take internal pressure 30 psi and to 350°F and with thermocouple outlets and thermostatic control to meet the temperature requirements of this process

3.5 Weighing equipment capable of an accuracy of 1/4 of one percent

3.6 Walk-in cooler or refrigerator capable of maintaining 40°F or below

3.7 Instrumentation as required by this process

4 Procedure

4.1 Mold Preparation

4.1.1 On new molds remove all grease, oil, and other surface contaminants with Naptha

A4.1.2 Coat the surfaces of the mold that come into contact with the molding material with a solution of [illegible] release.

4.1.3 After each molding remove all flash and foreign material from the mold. Use brass tools and compressed air

4.2 Preforming

A4.2.1 Cut the preimpregnated cloth in a pattern to form a layer of uniform coverage over the surface of the mold. Overlap each joint 3/4" $\pm$ 1/4"

A4.2.2 Heat each ply with heat gun to form the ply to contour and to debulk and bond each ply to the previous ply

A4.2.3 Continue operations 4.2.1 & 4.2.2 till desired number of plies have been placed in layup.

Note: Rotate overlap joints so that none accrue in same area

A4.2.4 Place nylon bleeder ply over layup

A4.2.5 Place two or more ply of cotton bleeder over nylon bleeder ply

A4.2.6 Vacuum bag part and check for vacuum leaks. Part should have a minimum of 25 inches Hg. during this period. Place part in oven and heat part to 170 + 10°F for 20 + 5 minutes allowing part to cool

+ 10°F -0 for 20 + 5 minutes -0 allowing part to cool outside oven with full vacuum till part researches room temp.

A4.2.7 Remove vacuum bag and bleeder material

A4.2.8 Remove preform from mold

A4.2.9 Trim preform using hand shears

5 Deployment of Wing Tank

A5.1 Molding (See paragraph 4.1, 4.1.1, 4.1.2 and 4.1.3)

5.1.1 Loading

C..1.1.1 Loading preform wing tank assembly into female thermo rubber bag or female mold. Vacuum bag part in female tool. Apply 30 psi total on part.

5.2.1 Molding and Curing

C5.2.1.1 Cure resin system at 335°F ± 10°F for 3 hours -0 + 10 minutes at 30 psi.

5.2.2.3 The molding pressure shall be removed only when the wing tank is cooled to a temperature of 190°F or below.

6. Material Storage

Store MRC-MS-001 material at or below 40°F in sealed polyethylene bags. Identity of the material shall be maintained Material shall not remain out of refrigeration more than 24 total hours prior to being used.

COLUMBUS DIVISION of NORTH AMERICAN ROCKWELL CORPORATION

PREPARED BY: G. A. Clark & J. G. Fasold	CODE IDENT NO 89372	NUMBER: ST0605HA0012
APPROVALS:	SPECIFICATION	TYPE: Process
		DATE: 2-13-69
		SUPERSEDES SPEC DATED 7-2-68
		REV LTR A / PAGE 1 OF 27

TITLE: FABRICATION OF EXPANDABLE RIGIDIZABLE EXTERNAL AIRCRAFT FUEL TANK (SO 4188)

LIST OF CONTENTS

FORM M-131-H-1 REV 10/67

(ϕ - INDICATES CHANGE)

1.0 SCOPE

1.1 This specification outlines the materials to be used and the procedures to be followed for fabricating a collapsible wing tank from composite materials.

1.2 This document describes the in-house fabrication of subassemblies and the on-site assembly of the complete structure. Provisions were made in the selection of materials and processes for the final assembly to accommodate relatively unsophisticated processing equipment normally available at on-site installations.

2.0 APPLICABLE DOCUMENTS, EQUIPMENT AND MATERIALS

2.1 Documents

Drawings

TT-17901 Tank-Complete, 150 Gallon Collapsible Wing, Assy. of (Test)
TT-17902 Hardback - 150 Gallon Collapsible Wing Tank Assy. of (Test)
TT-17903 Bulkhead-Collapsible Wing Tank, Assy. of (Test)
TT-17904 Clip-Bulkhead, Collapsible Wing Tank (Test)
TT-17905 Bushing-Collapsible Wing Tank, Suspension Lug (Test)
TT-17906 Fitting-Air Pressure Adapter, Collapsible Wing Tank (Test)
TT-17907 Bolting Ring-Collapsible Wing Tank, Assy. of (Test)
TT-17908 Fitting-Water Drain, Collapsible Wing Tank (Test)
TT-17909 Tank-Collapsible Wing, Assy. of (Test)

Sketch No. 3 Overlap Stations Parallel to the Longitudinal Axis
Sketch No. 4 Flat Patterns of Gores, Sheet 1
Sketch No. 5 Flat Patterns of Gores, Sheet 2
Sketch No. 6 Flat Patterns of Gores, Sheet 3
Sketch No. 7 Flat Patterns of Gores, Sheet 4

Specifications

MRC-MS-001 Specification for Impregnated Cloth for Making an Expandable Rigidizable Wing Tip Tank
MRC-MP-001 Wing Tank Manufacturing Process Specification
MIL-T-7378A Military Specifications Tanks, Fuel, Aircraft, External, Auxiliary, Removable
MIL-P-25421A Plastics Material, Glass Fiber Base-Epoxy Resin, Low Pressure Laminated
LA-0103-004 Tolerances and Processing of Machined Parts

2.2 Equipment

Tooling

Tooling shall be of metal, reinforced plastic or ceramic suitable for vacuum bag, autoclave or positive air pressure molding as required for the individual parts, assemblies or operations.

2.2 (cont'd.)

Hot Air Circulating Oven

A hot air circulating oven of sufficient size to enclose the largest part. The oven shall produce even heat, controlled to ± 5°F up to 335°F as indicated by thermocouples throughout the part.

Autoclave

An autoclave capable of molding materials up to nine (9) feet long and three (3) feet wide. Even temperature (± 10°F) to 350°F, augmented pressure to 50 psi, and vacuum of 25 inches of mercury are required.

Vacuum Pumps

For bag molding operations, vacuum pumps capable of 25 inches of mercury.

Automatic Temperature Recorder

Multiple channel recorder to continously record temperature cycle during the cure of resins and adhesives.

Cold Storage

Refrigerated boxes to maintain temperatures of 35±2°F and -10 ± 10°F for material storage.

Pressure Pump

Pressure pump capable of producing air pressure from 0 to 45 psi and regulated to ± 1 psi at any established point within the range.

Heat Gun

Electrically heated, blower type heat gun capable of producing and maintaining an air temperature of 300°F.

Sander

Mechanical type (jitterbug) operating on 110 volt, replaceable paper.

Sand Blast Equipment

Of sufficient size to enclose the largest part, requiring sanding. Must use clean silica sand.

Spray Equipment

Equipment must be capable of airless spraying of liquid adhesive primers.

2.2 (cont'd.)
Cleaning Tanks

A line of cleaning tanks capable of immersing the largest aluminum details. The line must contain acid etch, alkaline cleaner, water rinse, dionized water rinse and trichloroethylene vapor degrease.

Weighing Equipment

Must be capable of weighing to an accuracy of 0.25 percent up to three (3) pounds and within 1 percent above three (3) pounds.

Support Equipment

Equipment such as band saws, routers, drills, and other necessary for mechanical operations.

Miscellaneous

An assortment of layup benches, knives, scissors, rubbing tools, clean rags, clean white gloves, solvent cans, clamps, spatulas, mixing equipment and other miscellaneous items.

2.3 Materials

Productive

Epoxy Resin	MIL-R-9300
Catalyst	APCO 320 (Applied Plastics Co.)
Preimpregnated Fabric	MRC-MS-001 (Monsanto Research Corp.)
Film Adhesive	MMM-A-132 Type I, Class 2 (AF-126-2,3M Co.)
Paste Adhesive	MMM-A-132 Type I, Class 3(Bondmaster M602/M611(CH-1),PPG Industries)
Paste Adhesive Room Temperature Cure	MIL-A-8623 Type I (EC-2216, 3M Co.)
Glass Fabric	MIL-C-9084, Type VIII
Aluminum Core (Flexible)	Flexcore (Hexcel)
Aluminum Honeycomb Core	MIL-C-7438
Inorganic Filler	1557 AB Levigated Al_2O_3(B. Buehler Ltd.)
Thermocouple Wire	Iron-Constantan GG-30-AT 30 Gage Fiber Glass Shielded (Thermo Electric Co., Inc.)

2.3 (cont'd.)

Plastic Film	Hi-Temp Nylon Vacuum Bag Film (Nolan Film Co.)
Separator Sheet	TX1040 Teflon Fabric (Pallfex Products Corp.)
Dam Material	DK 153 Corprene-Adhesive Backed (Armstrong Cork Co.)
Mold Release	Mold Whiz 249
Mold Release	Duco #7 Wax (Dupont)
Mold Release	Kish 250A (Kish Plastics)
Mold Release	252-C Solution (Axel Plastics Research Lab.)
Aerodynamic Filler	MIL-S-8802, Class B

3.0 REQUIREMENTS

3.1 General Requirements

3.1.1 Certification of Materials

All materials shall be procured with certification for meeting the requirements of the applicable military specifications. Receiving-Inspection tests shall be conducted upon material receipt to assure conformance to the specifications unless a certified test report assuring specification conformance is supplied by the vendor.

3,1,2 Storage of Materials

3.1.2.1 Raw Materials

3.1.2.1.1 Epoxy Resins shall be stored in closed containers at 75 $\pm 10^{\circ}F$ but refrigeration (below $40^{\circ}F$) is permitted. When refrigerated, the resin shall be warmed to room temperature in closed containers to prevent moisture contamination.

3.1.2.1.2 Catalysts shall be stored in their original containers at 75 $\pm 5^{\circ}F$ with all precautions necessary to prevent contamination. A small amount (1 pint) of catalyst may be heated to 120 $\pm 10^{\circ}F$ in a tightly closed container immediately prior to use to facilitate mixing. If complete liquefaction is not achieved, all materials of that batch shall be scrapped.

3.1.2.1.3 Prepregged Materials shall be stored under refrigeration (Below $40^{\circ}F$) with the protective liner left intact. They shall be allowed to reach room temperature prior to removal of separator sheets. No more material

3.1.2.1.3 (cont'd.)

shall be left at room temperature than can be used within a 16 hour period.

3.1.2.1.4 Adhesives

3.1.2.1.4.1 AF-126-2 Film and EC-2320 Primer

3.1.2.1.4.1.1 The adhesive shall be stored at a temperature of 0°F or lower when not in use. The primer shall be stored at a temperature of 35°-45°F. Lower storage temperatures shall not be used for the primer in order to avoid freezing of this material.

3.1.2.1.4.1.2 Details to which adhesive or primer have been applied shall not be returned to refrigerated storage.

3.1.2.1.4.1.3 Maximum shelf life of the adhesive and primer described in this specification is 6 months from date of receipt from supplier if maintained per 3.1.2.1.4.1.1. Materials stored in excess of this period shall be referred to the Quality Assurance Laboratory for recertification or disposal.

3.1.2.1.4.2 Bondmaster M611 Adhesive, CH-1 Curing Agent and Bondmaster M-602, Parts I and II Primer

Storage life of the unmixed adhesive, curing agent and primer shall be a maximum of 6 months at 75F or one year at 40F (or below) from date of receipt from supplier. Materials stored in excess of this period shall be referred to the Quality Assurance Laboratory for recertification or disposal.

3.1.2.1.4.3. EC-2216 Adhesive, Parts A and B

Storage life of the unmixed adhesive shall be a maximum of 6 months at 75F or one year at 40F. (or below) from date of receipt from supplier. Materials stored in excess of this period shall be either scrapped or referred to the Quality Assurance Laboratory for recertification or disposal.

3.1.2.2 Woven Materials

Unimpregnated glass fabric may be stored at room temperature but shall be wrapped to preclude contamination from dust, dirt, oils and other contaminents.

3.1.2.3 Core Material

Metallic core must be stored in such manner as to prevent damage from stacking or handling.

3.1.2.4 Cured Material

Precured laminates, core and other details shall be stored in the "as-molded condition". They shall be interleaved with kraft paper and stored in such manner as to prevent contamination from dust, dirt, oil and handling.

3.1.3 Tool Preparation

The surface of the tool shall be highly polished and free of scratches, pits or foreign matter which would impair the parting, smoothness and cure of the laminate. The surface of the tool shall be coated with the parting agents listed below in accordance with the manufacturer's instructions. Where bag sealant will subsequently be applied, the tool must be masked prior to application of the release agent. Where the MCR-MS-001 material contacts any tool surface, regardless of the tool material only Mold Release 252C Solution shall be used and must be renewed after each laminating operation. Silicone Parting Agents such as DC-7 shall not be used.

3.1.3.1 Metallic Tool Parting Agent

Spray a double cross coat of Mold Whiz 249 air dried for five minutes and cured for 25 minutes at 225 ±10°F. This material need not be renewed until difficulty in part release is noted.

3.1.3.2 Non-Metallic Tool Parting Agent

Apply a coat of Duco #7 hard wax to the mold surface and polish to a high gloss. Spray a double cross coat of Kish 250A air dired 10 minutes between coats. This release must be renewed after each laminating operation.

3.1.3.3 Flat Surfaces - All Tool Materials

Cellophane or similar plastic film may be used where part configuration will not cause wrinkling of the film.

3.1.4 Processing Wet Resin Systems

3.1.4.1 Resin Formula and Impregnation

The following formula shall be used for impregnation of all glass fabric and shall be accurate to ± one (1) percent. The components shall be thoroughly blended prior to use and no more than a four (4) hour supply shall be mixed at one time.

3.1.4.1 (cont'd.)

Component	Designation	Parts by Wt.	Percent
Resin	EpiRez 510 or equivalent	80	78.4
Catalyst	APCO 320	22	21.6

3.1.4.2 Reinforcement Impregnation

All reinforcement shall be impregnated to 40% wet resin content by weight. The amount of resin formula required for any amount of glass is: the glass weight times 0.75. This allows a ten percent excess for resin loss. The resin may be applied by impregnation of each ply on the tool or, where large quantities if material are required, it may be applied by a doctor blade or similar equipment as detailed in paragraph 3.1.4.3.

3.1.4.3 Lay-Up Procedure

3.1.4.3.1 General

The engineering drawing will designate the type, direction and number of plies (laminations) of reinforcing fabric. Butt joints are not permitted and laps shall be held to a minimum. When laps are necessary they shall be held to 3/4±1/4 inch in width and, in successive plies, shall not be superimposed over one another. Tear or peel plies shall be added on all surfaces where secondary bonding is required within the limitation established in paragraph 3.1.7. Thermocouples shall be integral with all lay-ups for the purpose of controlling proper temperature of the resin during cure and the time-temperature history shall be recorded by automatic equipment. Location of the thermocouples shall be by Inspection.

3.1.4.3.2 Hand Impregnation

The reinforcing material shall be cut to pattern (allowing 1 to 2 inches for trim) and weighted to the nearest gram. The amount of resin formula shall be calculated and mixed in accordance with paragraph 3.1.4.1. A light coat of resin formula shall be spread over the tool surface which has been prepared per paragraph 3.1.3 and a ply of reinforcing material smoothed over the surface. Additional resin and reinforcement shall be added and smoothed out until B/P requirements are obtained.

3.1.4.3.3 Wet Preimpregnation

The fabric which has been impregnated by mechanical processes to the requirements of 3.1.4.2 shall be cut to pattern and applied to the tool previously prepared per paragraph 3.1.3. Plies shall be added individually and smoothed on the tool surface using a squeegee or similar tool. This smoothing operation is to eliminate wrinkles and pressure should not be such as to remove resin from the laminate.

3.1.4.4 Pressure Application and Curing of Woven Materials

3.1.4.4.1 General

Pressure shall be applied to the laminate during cure to insure intimate contact of mating parts. The pressure shall be constant and evenly distributed and may be applied by vacuum bag, autoclave pressure, positive pressure or combinations thereof.

3.1.4.4.2 Vacuum Bag and Cure Operations

3.1.4.4.2.1 Vacuum Bag and Rub-Out Operations

After the part has been laid up per paragraph 3.1.4.3 bag sealant material and hair-felt or bleeder material shall be positioned on the mold to allow a minimum of 3/4 of an inch between the bleeder and the edge of the lay-up and the bleeder mat during the rub-out. The peripheral bleeder shall be thicker, under vacuum, than the exposed edge of the part being made. The vacuum bag shall be tailored over the layup and sealed with zinc chromate putty. A vacuum hose shall then be connected so that it comes in contact with the bleeder mat. In no case shall the vacuum hose come in contact with the lay-up. Adequate vacuum ports shall be provided so that the vacuum never has to be pulled more than two feet in any direction. If greater distances are necessary, an expanded spring, adequately protected against bag rupture shall be used as a manifold. After the vacuum pressure is applied the bag wrinkles shall be worked out to a minimum. If necessary the vacuum may be removed for a few minutes in order to relax the bag and further remove wrinkles and the vacuum then reapplied. This must not be done after the resin starts to harden, or after rub-out has started. The vacuum bag shall be checked for leaks and a minimum pressure of 12½ psi or 25 inches of mercury must be maintained throughout the rub-out, pre-cure and cure cycles except as specified in paragraph 3.1.4.4.2.2.

3.1.4.4.2.1 (cont'd.)

Rub-out shall be accomplished with soft rub-out "paddles" or "squeegees" free from sharp edges. The rub-out shall be started near the middle of the part and worked toward all edges evenly, insuring a dam of continuous resin to trap air toward the outside of the part. The part may be heated to 140° ±10F (as determined by the thermocouples in the part) for no longer than 20 minutes maximum to facilitate rub-out. Rub-outs shall be continued until initial prominence of fabric weave and a continuous homogeneous appearance indicate sufficient rub-out has been accomplished. Excessive rub-out pressure can cause resin starved areas or results in a final part with too low a final resin content. (Optimum = 32 + 2 percent by weight). Rub-out is not required where matched tooling or pressure plates prohibit the operation. In these areas extra care must be exercised to eliminate wrinkles during lay-up.

3.1.4.4.2.2 Cure Cycle-Vacuum Bag Operation

Details containing the resin formula of 3.1.4.1 shall be cured by the following cycle. The temperatures shown are those of the part and not the heating system or the visible surface of the tool.

Condition	During Temp (°F)	(1) Time at Temp. (Minutes)
Pre-cure	170 ±10	60
Cure	250 ±10	60
Post-cure	325 ±10	120

1. Time at temperature is the actual minimum time for the part to be at the temperature shown for the specific condition. This temperature shall be established by thermo couples in the part. Temperatures shall be automatically and continuously recorded during the heating and cooling cycles.

2. The time for the part temperature to reach 170 ±10°F (precure) shall be 25 ±5 minutes. Heat up rate for other conditions may be maximum obtainable with the equipment and still hold required temperature tolerance.

The part shall remain under pressure for the complete pre-cure and cure cycle. Vacuum bag pressure may be released for the post-cure but the parts shall not be removed from the tool until they have cooled to 150°F maximum.

3.1.4.4.2.3 Autoclave Pressure Molding and Curing

The laminate shall be laid-up in accordance with paragraph 3.1.4.3. Around the periphery (within 1/4 inch) place a dam of adhesive backed rubber impregnated cork (Corprene DK 153). Place a separator sheet (TX 1040) over the lay-up extending over the dam. Place bleeder fabric over the separator sheet and extending over the manifold vacuum (expanded spring wire). The number of bleeder plies shall be established as follows:

Using: 181 fabric - 1 ply for each three plies of 181 within the lay-up

1557 fabric - 1 ply for each two plies of 181 within the lay-up

Position thermocouples and vacuum bag the entire lay-up, making sure there are no leaks in the bag or around the periphery of the part. Allow the part to stand for 30 minutes, under full vacuum but with no heat applied. Place the package in the autoclave with full vacuum pressure (25 inches of mercury) and apply heat per paragraph 3.1.4.4.2.2(2). When the part reaches 130°F, again allow to dwell for 30 minutes. Apply 50 psi positive presure at the maximum rate of the equipment. When the pressure reaches 25 psi, remove the vacuum and allow the part to be vented to the atmosphere. Increase the temperature to 170°F and continue cure paragraph 3.1.4.4.2.2.

3.1.5 Processing of "B" Staged Resin-System

3.1.5.1 Lay-Up

The preimpregnated material shall be cut to pattern as per Flat Pattern of Gores, Sketches 4, 5, 6, and 7 and uniformly placed in individual plies on the tool. Any laps shall be limited to 3/4 ± 1/4 inch and shall be staggered to minimize thickness build up in any one area, as per Sketch 3, Overlap Stations Parallel to the Longitudinal Axis. Each ply shall be heated with a heat gun to "weld" successive plies to the previous ply. As each layer is applied, it shall be smoothed onto the surface using a squeegee or similar tool. This operation eliminates wrinkles and reduces the uncured thickness of the detail. The operation shall be continued until drawing call out thickness is achieved.

3.1.5.2 Compaction

Thermocouples shall have been or will be placed against the lay-up where it is believed will have the slowest heat-up rate. Pressure shall be applied and, if by vacuum, the assembly will be checked for leaks in accordance with paragraph 3.1.4.4.2.1. Full vacuum or 15 psi positive pressure shall be applied and the assembly heated to 170 $\pm 10^{o}$F. This temperature shall be maintained for 27.5 $\pm$2.5 minutes. The heat shall be removed from the part but pressure shall be maintained for 12 hours.

3.1.5.3 Cure

Cure of the compacted assembly shall be accomplished at 335 $\pm 10^{o}$F for 3 hours minimum under 30 psi (autoclave pressure required for vacuum bagged parts). The cure time shall be started when the coldest thermocouple reaches 325^{o}F. The part shall be allowed to cool, under full pressure, to 190^{o}F on the hottest thermocouple before removal from the tool. Remove air pressure before removing part from tool.

3.1.6 Fabrication and Prefitting of Detail Parts

Metal and precured details that will be used as part of a composite assembly shall be fabricated such that when prefit prior to fabrication, will conform to the following requirements:

3.1.6.1 The honeycomb core blanket shall not deviate from the required thickness dimension by more than $\pm$ .005 inch.

3.1.6.2 The juncture of abutting honeycomb core blankets and metal or precured reinforced plastic details shall not deviate in thickness by more than $\pm$ .010 inch.

3.1.7 Surface Preparation of Details for Bonding

3.1.7.1 General

Both metal and precured reinforced plastic surfaces shall be prepared immediately prior to bonding unless otherwise noted in the Detail Requirements. The surface preparation varies with the type of material to be bonded. Specific methods are presented below.

3.1.7.2 Precured Fabric Laminates (0.030 Inch or Greater)

These surfaces shall be prepared by removal of a peel ply or plies incorporated into the initial lay-up. This operation will be accomplished wearing clean white gloves, using clean tools to initiate peel, and in an area where contaminants will not be deposited on the cleaned surface during or after the operation. Where contour will not permit removal of plies, the surface shall be prepared in accordance with the procedure for "Fabric Laminates - Less than 0.030 Inch".

3.1.7.3 Precured Fabric Laminates (Less Than 0.030 Inch)

These surfaces shall be thoroughly scuff sanded preferably with a jitterbug using 200 grit sandpaper, followed by solvent cleaning per paragraph 3.1.7.4. Surfaces shall be considered satisfactorily prepared when all resin gloss has been removed from the laminate surface. In no case may the sanding extend through a ply of the reinforcing fabric.

3.1.7.4 Solvent Cleaning

3.1.7.4.1 Handling of Solvent

Within one hour prior to adhesive application, all sanded bonding surfaces shall be hand cleaned with clean cheesecloth and methyl ethyl ketone. The solvent used shall have been previously certified as free from contaminants and shall be stored in a separate container which has been identified for solvent cleaning use only. This solvent shall be applied by pouring onto the clean white cheesecloth; this will eliminate contact of the solvent supply with the cleaning tissue and reduce the possibility of solvent contamination.

3.1.7.4.2 Solvent Cleaning Procedure

Bonding surfaces shall be vigorously scrubbed with solvent-saturated cloths and immediately wiped dry with additional clean tissues before the solvent has evaporated. Surfaces upon which the solvent has been allowed to air dry are not suitable for adhesive bonding. Clean rubber gloves shall be worn throughout the solvent cleaning operation. A minimum of three separate solvent application-wipe dry operations shall be performed on all bonding surfaces; additional cleaning cycles shall be used, if required, until fresh white drying tissues show no trace of discoloration.

3.1.7.5 Aluminum Details

3.1.7.5.1 General Requirements

Subsequent to all pre-fit operations and pre-treatment per Table I, all aluminum bonding surfaces shall be treated per Table II as soon as possible prior to adhesive application. Unless otherwise specified on the applicable engineering drawing, adhesive primer shall be applied to the bonded area within 24 hours after final cleaning. Details exceeding maximum allowable time limits shall be recleaned.

3.1.7.5.2 Water Break Inspection

All metal surfaces cleaned by immersion methods in acids or similar chemicals shall be thoroughly rinsed with water subsequent to chemical treatment. After rinsing, all surfaces shall be inspected to insure that a "water-break free" condition exists, i.e. the water film is continuous over the entire surface. Details which exhibit a break in the water film shall be recleaned until no water break is observed. After final rinsing and inspection, details may be either air or force dried at temperatures not to exceed 150F. All parts must pass water break test one (1) hour before primed.

3.1.7.5.3 Handling of Cleaned Details

After final cleaning, details shall be handled with clean white cotton gloves only. If transporation is required between the cleaning and bonding areas, details shall be protected by wrapping in fresh, clean kraft paper.

3.1.7.6 Aluminum Honeycomb

Vapor degrease in trichloroethylene. Handle in accordance with 3.1.7.5.3.

TABLE I

SURFACE PRETREATMENT - ALUMINUM DETAILS

STEP	OPERATION
1	Remove all organic finishes (paints, primers and similar coatings) from bonding surfaces with an immersion stripper. Alternate Method Remove by sanding with 180 grit abrasive paper and solvent wiping with methyl ethyl ketone. Use only where immersion or brush-on strippers cannot be employed because of possible solution entrapment.
2	Remove chemical films or anodic coatings from bonding surfaces (aluminum alloys only) with either an immersion or abrasive stripper.
3	Solvent clean to remove all grease, oils, ink markings, fingerprints, etc. with methyl ethyl ketone.
4	Vapor degrease in trichloroethylene

TABLE II

ALUMINUM ALLOYS - IMMERSION PROCESS

STEP	OPERATION	CONSTITUENTS	TEMP, F.	TIME, MINUTES	REMARKS
1	Surface pre-treatment				Pre-treat bonding surfaces per Table I
2	Alkaline Clean	Commercial Alica-line Cleaner	165-175F	10-15	Constant agitation required during cleaning
3	Immersion rinse	Hot water	150-160F	5 Min. Minimum	Inspect for "water-break free" surface per Paragraph 3.1.7.5.2
4	Acid Etch	Sodium Dichromate 1 part, Sulfuric Acid 10 Parts, Distilled or Deionized water 30 parts, all by weight	150-160F	10+2 -0 Minutes	Constant agitation required during immersion
5	Spray Rinse	Distilled or Deionized Water	Room	As Req'd.	
6	Immersion Rinse	Tap Water	Room	As Req'd.	Constant overflow mandatory
7	Spray Rinse	Tap Water	Room	As Req'd.	
8	Inspection				Inspect for "water-break free" surface per Paragraph 3.1.7.5.2
9	Dry	Oven (forced air) air dry	150F Maximum	As Req'd.	

3.1.8 Priming of Details

3.1.8.1 General

Unless otherwise specified on the engineering drawing, all metal details bonded to the requirements of this specification shall be primed. Primer shall be applied within the allowable time limits of 3.1.7.5.1. Primer shall not be applied to bonding surfaces specifically called out on the applicable engineering drawing.

3.1.8.2 Primer Application and Cure

3.1.8.2.1 EC-2320 Primer

3.1.8.2.1.1 This primer shall only be used in conjunction with AF-126-2 adhesive, when applicable.

3.1.8.2.1.2 The EC-2320 primer is supplied in liquid form and may be applied by brushing or may be sprayed using conventional spray equipment. Apply sufficient primer to produce a dried film thickness of .0002 to .0005 inches. Air dry for a minimum of 30 minutes followed by a force dry of 30 minutes of 210 $\pm$ 10F.

3.1.8.2.2 Bondmaster M-602 Primer

3.1.8.2.2.1 This primer shall only be used in conjunction with the Bondmaster M-611 adhesive/CH-1 catalyst system when applicable.

3.1.8.2.2.2 Stir or mechanically shake parts I and II of the M-602 adhesive primer to disperse any unsuspended material before combining them to form the primer spray solution. After parts I and II have been individually agitated, combine to form the primer spray solution as follows: Add 5 parts of I to 4 parts of II, by weight, and mix thoroughly. Dilute the primer spray solution as follows: Add 2-1/2 parts of methyl ethyl ketone (MEK) to 1 part of primer spray solution, by weight, and mix thoroughly.

3.1.8.2.2.3 The catalyzed M-602 adhesive primer solution is now ready for use. If the material is not to be used immediately, it shall be stored in closed containers to prevent solvent loss by evaporation or contamination. Place filled containers in a cool place and use within a maximum time of three days.

3.1.8.2.2.4 Spray the bonding surfaces of the sheet metal components, except the core, with the prepared M-602 adhesive primer to a uniform, smooth surface thickness of .0005-.0009 inches. This may be accomplished by spraying several light box coats of the primer using conventional spray equipment with an air pressure of about 25 psi.

3.1.8.2.2.5 All spray primed parts shall be air dried for a minimum of 30 minutes after the final coat to permit partial evaporation of the solvent in the primer. During the drying period care shall be exercised in protecting the parts against contamination.

3.1.8.2.2.6 The parts shall be force dried in a circulating air oven at 230-250F for 30 ± 5 minutes.

3.1.8.2.2.7 After force drying, the primed parts shall be cured at 330-340F. in a circulating air oven for 60 ± 5 minutes after the part has reached this temperature range.

3.1.8.3 Handling of Primed Details

Handle all primed details with clean white cotton gloves only. After curing of primer, protect details by wrapping in fresh draft paper until use. These parts shall be bonded as soon as possible after curing.

If delays in bonding are unavoidable, parts with cured primer shall be stored in a clean dry place, but not to exceed a period of 60 days prior to bonding. Cured primer shall be cleaned immediately prior to adhesive application by solvent cleaning in accordance with Para. 3.1.7.4 using fresh naptha or MEK.

3.1.9 Adhesive Application & Cure

3.1.9.1 AF-126-2 Adhesive

3.1.9.1.1 Adhesive Description

AF-126-2 adhesive is a modified epoxy impregnated into a mat type synthetic film carrier. The adhesive is supplied in film form with a heavy paper liner on the outer surface only.

3.1.9.1.2 Handling of Adhesive

Upon removal from refrigeration, allow the outer layers of adhesive to warm to room temperature before unrolling to avoid cracking of the film or moisture condensation on the adhesive surface. Return adhesive to refrigerated storage immediately after the amount of adhesive required for use is removed to avoid overaging of the material. Use clean white gloves.

3.1.9.1.3 Application of Film Adhesive

The AF-126-2 adhesive is a very tacky film and care must be excerised in application to bonding surfaces. Wherever possible it is suggested that the detail to be bonded be used as a template in cutting adhesive patterns. Clean bonding surfaces per 3.1.7 immediately prior to adhesive application. Allow the outer separator sheet to remain inposition until immediately prior to assembly of details.

3.1.9.1.4 Application of Thixotropic Paste Adhesive

The past adhesive shall be employed in bonding of all honeycomb sandwich assemblies (and in other edge bonding applications where specified on the applicable drawing). Composition of the paste shall be as follows: Mask off area not to be bonded.

3.1.9.1.4 (cont'd.)

Material	Parts by Weight
Bondmaster M-611 Adhesive	100
1557AB Levigated Aluminum Oxide	100
Curing Agent CH-1B	6

Pre-mix adhesive and aluminum oxide. Add the curing agent to the adhesive-aluminum oxide mixture and blend until a uniform color is produced. The paste material shall be applied to the side mating surfaces of all honeycomb details i.e. core edges, inserts, closout members, core splices, etc. Apply the paste i s thin continuous film to both mating surfaces. Working life of the mixed adhesive is approximately two hours.

3.1.9.1.5 Pressure Application

After assembly of details, sufficient pressure to assure intimate contact of details shall be applied by vacuum bag, autoclave or clamps. In all applications, minimum pressure utilized shall be 10 psi (20 ± 2 inches of mercury if vacuum bag pressure is employed).

3.1.9.1.6 Curing of Adhesive

Raise temperature to 250 ± 15F and cure for 60 to 75 minutes. Heat up rates of 15 minutes to 3 hours may be employed. In all applications, at least one thermocouple shall be placed on the lower surface of the assembly in such a position that the lowest anticipated temperature will be read.

The maximum elapsed time between application of the adhesive to the bonding surface and the beginning of the cure cycle shall be 48 hours.

3.1.9.1.7 Cooling of Cured Adhesives

Cooling rates after cure are not critical. Full bonding pressure shall be maintained, however, until temperature of the assembly has dropped to at least 150°F.

3.1.9.2 Bondmaster M-611 Adhesive/CH-1B Curing Agent

3.1.9.2.1 Mixing Instructions for Adhesive

3.1.9.2.1.1 Add one part, by weight, of "Monastral Blue" Pigment to fifty parts, by weight, of the curing agent, CH-1B. Stir or shake well to disperse particles; then add six parts of pigmented mixture to 100 parts, by weight, of the paste of Bondmaster M-611 and stir until the mix becomes a uniform shade of blue - that is, until no streaks are observable in the blend.

3.1.9.2.1.1 continued

CAUTION:

TOXIC FUMES ARE GIVEN OFF DURING THE MIXING OPERATION. TO MINIMIZE THE DANGER OF THESE FUMES, OBSERVE THE FOLLOWING PRECAUTIONS:

1. Add Activator slowly.
2. Cool the paste prior to mixing.
3. Mix in quantities of one quart or less.
4. Ventilate the mixing area.
5. Do not breathe the vapors.
6. Keep the activator off hands and clothing.

3.1.9.2.1.2 After the curing agent has been blended, there is no fuming, but prolonged contact of blended adhesive with skin should be avoided.

3.1.9.2.2 Application of Mixed Paste Adhesive

3.1.9.2.2.1 Pot Life

The adhesive should be applied as soon as possible after adding the curing agent. The useful pot life of the catalyzed adhesive is approximately one hour after which it may become too thick to spread and should not be used. Refrigeration prolongs the pot life but is practical only when the adhesive is in small batches that can be cooled quickly.

3.1.9.2.2.2 Application

The adhesive may be applied with a spatula, putty knife, glue-spreader, or other suitable means such as squeezing from tubes or from pressure guns. It should be applied in a continuous film to both bonding surfaces where possible. The coat should be thick enough to fill any voids that are left as the result of malformed mating surfaces, etc. Mask off areas not to be bonded.

3.1.9.2.2.3 Care should be taken to mask external surfaces from "Squeeze-out" and clean off excess cement from these surfaces prior to curing. After curing, the cement is difficult to remove. Clean all spreading and mixing equipment with acetone immediately after use.

3.1.9.2.3 Pressure Application

The only pressure required during cure is that needed to keep parts in alignment and to overcome distortion and thermal expansion of the adherends.

3.1.9.2.4 Curing of Adhesive

3.1.9.2.4.1 General

The assembly shall be cured as soon as possible after cleaning the bond to insure proper wetting of bonding surfaces. Maximum elapsed time between mixing of adhesive and closing the bond shall not exceed 3 hours for all bonded details.

3.1.9.2.4.2 Primed Details

All assemblies utilizing M-602 primer shall be cured at a bond line temperature of 250F ± 10F for 75 ± 10 minutes. Warm up time shall not exceed 45 minutes. Bonding pressure shall be maintained throughout the cur.

3.1.9.2.4.3 Unprimed Details

Assemblies not utilizing M-602 primer shall be cured either 1) as specified in Paragraph 3.1.9.2.4.2 above or 2) at a bond line temperature of 170 ± 10F for 3 hours. Selection of the cure cycle used, for unprimed parts only, shall be at the discretion of the using manufacturing department.

3.1.9.2.4.4 Cool the assembly to 125F maximum before removing pressure.

3.1.9.2.5 Cleaning Up

3.1.9.2.5.1 Remove excess cement with wiping rags wet with methyl ethyl ketone. This must be done a few minutes after applying the cement.

3.1.9.2.5.2 Clean all spreading and mixing equipment with methyl ethyl ketone immediately after use.

3.1.9.2.5.3 Cured adhesive residues and primer, that cannot be removed by filing or scraping, may be removed with a suitable stripper. This stripper may be applied with a brush, care being taken to prevent penetrationinto seams, joints, crevices where removal may prove difficult. After a few minutes of soaking the adhesive residues and primer are removed with a soft scraper such as a tongue depressor. Clean the stripped surface with a rag dampened with water ans wipe with a dry rag.

3.1.9.2.5.4 Adhesive should be cleaned from hands with soap and water and stiff brush. The use of solvents should be avoided.

3.1.9.3 EC-2216 Adhesive

3.1.9.3.1 Mixing Instructions for Adhesive

3.1.9.3.1.1 Mix 140 parts by weight of Hardener "A" to 100 parts by weight of Base "B". Stir thoroughly for a minimum of five minutes or until uniform mixing has been obtained.

3.1.9.3.1.2 The working life of the mixed adhesive is two hours in 100 gram masses. Adhesive which has not been applied within this period of time, after mixing, shall be discarded.

3.1.9.3.2 Application of Mixed Paste Adhesive and Cure

3.1.9.3.2.1 Apply a smooth coat of adhesive, three to five mils, to each surface to be bonded. The adhesive may be applied by means of a spatula, notched trowel or tongue blades. Mask off areas not to be bonded.

3.1.9.3.2.2 Press or roll both surfaces together to eliminate possible formation of air bubbles and to insure intimate contact between faying surfaces. The only pressure needed during the cure of mixed EC-2216 is that required to keep parts in alignment and to overcome distortion and thermal expansion of the adherends.

3.1.9.3.2.3 The adhesive may be cured as follows:

72 hours at room temperature
or
4 hours at 130 to 150°F

Note: Sufficient cure can be obtained in twenty-four hours at room temperature to remove clamping pressure but the parts should not be stressed for seventy-two hours.

3.1.9.3.3 Cleaning Up

Cleaning shall be in accordance with paragraph 3.1.9.2.5.

3.2 Detailed Requirements

Fabrication of all details and assembly shall be in accordance with the requirements of this paragraph and paragraph 3.1 as applicable.

3.2.1 Hardback (TT-17902)

3.2.1.1 Prefabricated Details

All prefabricated details (-15, -17, -25, -27, -29, -33 and -35) shall be fabricated in accordance with paragraph 3.1.4 using vacuum bag pressure. All details shall be trimmed and machined to blueprint requirements. The -7, -9 and -13 core materials shall be processed in accordance with paragraphs 3.1.6, 3.1.7.6, 3.1.8.2.1 and 3.1.8.3.

3.2.1.2 Installation of P/N's TT-17905, TT-17906 and TT-17908 Bushings and Fittings

The noted bushings and fittings shall be bonded into the hardback with Bondmaster M-611 adhesive per the procedure described in Paragraph 3.1.9.2. Prior to installation, the bushings and fittings shall be primed with Bondmaster M-602 primer in accordance with the procedure described in paragraph 3.1.8.2.2.

3.2.1.3 TT-17902-1 Assembly

Dry fit all parts to assure perfect fit. The surface of the male tool shall be prepared in accordance with paragraph 3.1.3. The -19 skin shall be laid-up in accordance with paragraph 3.1.4 and the material at the location of the 431-9 fuel cap removed. Apply adhesive per paragraph 3.1.9.1. over the entire lay-up area. Preassembly the -15 close out, the -7, -9, and -13 cores per 3.1.9.1.4. Position this subassembly on the material laid-up on the tool. Apply the same adhesive (3.1.9.1) to cap. Apply adhesive (AF-126-2) to the outer surface of the 431-9 and the edge of the hole and insert the -27 filler. Apply AF-126-2 adhesive over the entire surface and lay-up the -3 skin. Bag and cure in accordance with paragraph 3.1.4 using vacuum bag pressure. Trim as required. Installation of other parts and details is presented in paragraph 3.2.1.4.

3.2.1.4 TT-17902-11 Assembly

The processing sequence for this assembly shall be identical to the -1 assembly except the -5 and -23 skins, the -17 and -29 fillers and the HE193-5002-0007 filler cap shall replace the -3 and -19 skins, the -15 and -27 fillers and the 431-9, respectively.

3.2.2 Bulkhead (TT-17903) and Clips (TT-17904)

3.2.2.1 Skins (-3)

The -3 skins shall be fabricated using 181E glass fabric, the resin formula of paragraph 3.1.4.1, impregnated by the method of either 3.1.4.3.2 or 3.1.4.3.3, laid up in accordance with 3.1.4.4.2.1 and cured in accordance with 3.1.4.4.2.3. Parts shall be trimmed, surfaces prepared per 3.1.7 and stored in accordance with 3.1.2.4.

3.2.2.2 Clips, Zee Sections and Slosh Baffle (TT-17903-7, -9, -15 and -17, TT 17904-3 and -4)

The clips, zee sections and slosh baffles shall be fabricated using 181E glass fabric, the resin formula of paragraph 3.1.4.1, impregnated by the method of either 3.1.4.3.2 or 3.1.3.3.3, and laid up and cured in accordance with 3.1.4.4.2.1. Parts shall be trimmed, surfaces prepared per 3.1.7 and stored in accordance with 3.1.2.4.

3.2.2.3 Core Material (-5)

The core shall be machined, cleaned and handled until used, in accordance with paragraphs 3.1.6, 3.1.7, and 3.1.7.6.

3.2.2.4 Assembly of TT-17903

Dry fit all parts to assure perfect fit. The -3 skins and the -5 core shall be bonded with AF-126-2 adhesive in accordance with the procedure described in paragraph 3.1.9.1. The parts shall be trimmed to blueprint requirements and the -7 and -9 clips, and the -13 channels secondarily bonded using AF-126-2 in accordance with paragraph 3.1.9.1.

3.2.3 Bolting Ring (TT-17907)

The -1 and -11 assemblies are identical except for size. Only the fabrication of the -1 will be discussed but that information will be applicable in all respects to the -11.

3.2.3.1 Ring and Pan (-3 and -5)

The parts shall be laid-up and cured in accordance with paragraph 3.1.4.4 using 181E glass fabric prepared per paragraph 3.1.4.

3.2.3.2 Assembly (TT-17907-1)

The nut plates required for attachment shall be riveted onto the ring. The ring and pan shall be bonded with AF-126-2 adhesive in accordance with paragraph 3.1.9.1. A bond shall be effected at all contact areas between the two mating details. Final trim and prepare surfaces per paragraph 3.1.7 for final assembly.

3.2.4 Tank (TT-17909)

3.2.4.1 TT-17909-5

This part is to be precured prior to incorporation into the basic tank. The tool shall be processed in accordance with paragraph 3.1.3 and 15 plies of material laid up and compacted in accordance with paragraph 3.1.5.2. This sequence shall be repeated until the required thickness and taper are achieved. The bag, under vacuum, shall be left on the lay-up, a lubricant applied and the female tool positioned. Pressure shall be applied by conventional bagging and 30 psi autoclave pressure, with cure accomplished in accordance with paragraph 3.1.5.3. After removal from the tool, the surfaces of the part shall be prepared for bonding per paragraph 3.1.7.

3.2.4.2 Assembly (TT-17909)

Before starting this lay-up, consider thermocouple requirements and, if necessary incorporate prior to part lay-up. Prepare the tool surface in accordance with paragraph 3.1.3. Lay-up one-half the required material in accordance with paragraph 3.1.5.1, and position the -5 insert on which AF-126-2 adhesive has been applied per paragraph 3.1.9.1. Lay-up the remainder of the material as above. Position the lay-up in the split female tool whose surfaces have been prepared in accordance with paragraph 3.1.3. Compact in accordance with paragraph 3.1.5.2. Upon completion of this step, turn on the water in the cooling coils and complete the cure of the area shown in Section A-A of drawing TT-17909 in accordance with paragraph 3.1.5.3. Remove female tool. Deflat male tool, but leave the bag in the assembly, and trim the fore and aft openings, the saddle opening and route the "O" ring groove. Position the hardback and drill attaching holes through the hardback and the skin. Locate the bulkheads, re-position the hardback and pilot drill the bulkhead flange. Remove the bulkhead, drill the attaching holes, and mount the necessary nut plates.

3.2.4.2 continued

Fold the aft end of the tank at T.S. 102.00 (or closer to the landing if possible), and then fold the forward end at T.S. 52.00 (or closer to the landing if possible), into the hard-back area. Part is ready for shipment.

3.2.5 Final Assembly (TT-17901)

Carefully unfold the ends and with hand pressure, wearing clean rubber gloves, smooth the compacted material to essentially mold line contour. Insert the part in female tool. Cover up nut plates with a smooth cloth or foam rubber and cure in accordance with paragraph 3.1.5.3. Remove nut plate cover cloth or foam rubber. Reposition the bulkheads. Apply EC-2216 adhesive to the faying surfaces of the TT-17903-3 and -4 flanges, position against the tank and bulkhead and cure. These operations are covered by paragraph 3.1.9.3. Using the same process, attach the TT-17907-1 and -11. Install all internal plumbing. Install the MS29513-010 "O" ring. Apply a light coat of petroleum jelly to the edge of the hardback. Mechanically fasten the hardback to the tank. Install, with mechanical fasteners, the nose and tail assemblies. Finally, fare the joint between the hardback and the tank with MIL-S-8802 Class B, Sealant.

4.0 Quality Assurance

Conformance of production to the requirements of paragraphs 3.1 and 3.2 is the responsibility of Inspection.

4.1 Control of Adhesive Materials

4.1.1 Receiving Inspection Tests

Receiving Inspection Tests shall be conducted on all incoming adhesive materials for certification to the acceptance requirements listed in applicable material specifications.

4.1.2 Inspection

All bonded assemblies shall be inspected for conformance to the engineering drawing. In addition, each assembly shall be verified to be 100 percent void free either by sound tapping (coin or inspection tapping device) or by means of ultrasonic equipment (Coindascope, Reflectoscope, etc.).

4.1.3 Records

Suitable records governing control of the entire bonding process, final inspection and process control test results shall be maintained by Quality Control for each production assembly. These records shall contain the serial number of the assembly they represent so that future identification is readily accessible.

4.2 Final Inspection

The final tank assembly shall be inspected for defects after completion of fabrication. A record of inspection shall be prepared which will include a detailed description of all noted defects in the assembly. These defects shall be reviewed by the Project Engineer to determine which defects are allowable and the corrective action necessary for those defects that need corrective action. The recommendations for these corrective actions will be reviewed with the Buyer for his concurrence and/or comments prior to any corrective action.

4.3 Corrective Action

All corrective action agreed to by the Project Engineer and the Buyer shall be conducted subsequently to final inspection described in paragraph 4.2.

5.0 Preparation For Delivery

Each individual part comprising the assembly shall be identified by a rubber stamp marking. This shall be accomplished by cleaning the area, to be stamped, with naptha or methyl ethyl ketone for the purpose of removing any grease, oil, dirt or other contaminates. Apply the applicable marking with a rubber stamp using permanent black ink.

6.0 Notes

The final inspection procedure described in paragraph 4.2 will include participation of US Air Force representative as deemed necessary by the Buyer.

SEQUENCE OF OPERATION REQUIRED

FOR TOOL HSK 976

THE MANDREL FORMING TOWER

SET UP AND LOADING OF

SILICONE MANDREL BAG

SCALE	REVISED 1-16-69		
DRAWN C. E. KOONTZ	DATE 8-20-68	COLUMBUS DIVISION NORTH AMERICAN ROCKWELL CORPORATION	
CHECKED	DATE	MANDREL TOWER HSK 976	
APPROVED	DATE 8-20-68		

OPERATION

1.0.0 <u>ASSEMBLING BAG TO A[illegible] AND LOADING IN [illegible] FORMING TOWER</u>

1.1 Assemble the center post Det. -207 and the two end locators (Dets. -203 and -210) with -141 pins. Also Det. 206 pipe and cap.

1.2 Pull the bag over the post by inserting the small end of the assembled post into the large nozzle opening of the bag. Pull the bag up on the post until the small nozzle end of the bag is even with the step in the shaft end Detail -210. Wrap the bag nozzle end with a minimum of five (5) wraps of cloth or tape to protect the bag nozzle and apply a steel band, screw tightening clamp to the bag nozzle.

1.3 Pull the large nozzle end of the bag up until it locates on the shoulder of detail -203. Apply a minimum of five (5) wraps of cloth or tape around the nozzle area of the large bag end and apply a steel band, screw tightening clamp to the bag nozzle. Bag seam is to be 90° rotation from tapped hole coded up in Detail -203 and in line with the tapped hole that is 90° to the tapped hole coded up.

1.4 Install Detail 212 lifting lug on Detail 210 shaft and standard eyebolt in Detail 203 in preparation to lift mandrel.

1.5 Place the bag with the shaft and end blocks clamped in place in the final oven and electrically curing tool and in the lay-up trunnion and check for clamp clearance to these tools. Readjust as required for clearance.

1.6 Place the bag assembly in the mandrel forming tower tool with the bag seam line (180°) opposite the saddle door area.

1.7 Inspect the bag as mounted to the mandrel for possible leaks and the clamped nozzle ends.

1.8 Deflate the bag completely and secure to mandrel with masking tape to avoid tearing or damage when loading into tower tool.

1.9 Place half of detail 211 bushing in detail 140 tower tool and load steel mandrel and bag into tool.

1.10 Remove masking tape and place bag seam down center of mandrel. Place second half of detail 211 bushing over shaft detail 210.

1.11 Remove lifting lug detail 212 and eyebolt from detail 203.

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1.12 Index the top half of the tool to the bottom half of the tool by lowering the top half of the tool onto the brass index pins

1.13 Bolt the two halves together and add the clamping ring (Det. -201) to the large end of the tool.

1.14 Apply the vacuum hose to the small end of the tool. Shut the shut off valve and check the vacuum pump. If the pump stays off, then there is no vacuum loss indicating the shut off valve is shut off and holding.

1.15 Inflate the mandrel bag with five (5) pounds of positive pressure. At this time, a check for leaks in connections should be made. Repair leaks as required. (Tool is horizontal)

1.16 Lift the tower mandrel forming tool into vertical position and set it down on the vibrator table with the small end of the tool down.

Note the vacuum hose should be tucked into the frame work of the vibrator table in such a way as to allow the Tower Mandrel Forming Tool to be lifted from the vibrator table and returned to a horizontal position on the floor without disconnecting the vacuum line or loosing vacuum pressure. Tack weld or bolt and brace the Tower Mandrel Forming Tool to the vibrator table as required.

1.17 Attach the nodule hopper to the Tower Mandrel Forming Tool.

2.0.0 THE FILLING OF THE MANDREL BAG WITH NODULES

2.1 Close the shut off valve between the nodule hopper and the tower tool and connect the air pressure line to the large end of the tower tool.

2.2 Fill the nodule hopper with nodules to approximately three (3) inches from the top of the hopper.

2.3 Cap the fill hole and apply five (5) pounds of positive air pressure to the nodule hopper.

2.4 Start the vibrator, open the nodule hopper shut off valve and check the nodule flow through the clear plexiglass tube between the nodule hopper and the tower tool. If the nodule flow is not in a steady free flow, the positive pressure in the nodule hopper should be increased slightly until an even free flow is optained.

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OPERATION

2.5 When the nodules cease to flow in a steady stream indicating the nodule hopper is empty, close the shut off valve between the nodule hopper and the tower tool. Turn off the vibrator. Release the pressure from the nodule hopper.

2.6 Repeat Operation 2.3 through 2.6 until the plexiglass tube is filled with nodules indicating the mandrel bag and large end of the tower tool is filled completely with nodules.

3.0.0 THE RELEASING OF THE POSITIVE PRESSURE AND APPLYING THE VACUUM PRESSURE TO THE MANDREL.

3.1 Close the shut off valve to the nodule hopper. Disconnect the nodule hopper from the tower tool at the tower tool end of the plexiglass tube.

3.2 Remove the fill adapter (Detail -202) and the air hose from the Detail -108 "O" seal adapter.

3.3 Remove the Detail -109 cap from the Detail -206 vacuum tube. Apply the Detail -109 cap to the Detail -108 "O" seal adapter to seal off the positive pressure parts in the large bag end Detail -203.

3.4 Clear all nodules from the large bag end Detail -203 in the vacuum seal attach area. Insert the -110 seal into place. Screw Detail -204 into the large bag end Detail -203. Screw Detail -205 seal nut into the -204 detail sealing off around the -206 vacuum tube. Attach the vacuum hose and apply twenty (20) inches mercury minimum vacuum to both ends of the mandrel in the tower mandrel forming tool.

3.5 Check all lines and connections for leaks and repair them as required. Note vacuum pumps should shut off and hold a minimum of twenty (20) inches of mercury vacuum without any appreciable amount of vacuum leakage or decrease in pressure.

4.0.0 REMOVAL OF THE FORMED VACUUM CONTAINED MANDREL FROM THE TOWER MANDREL FORMING TOOL

4.1 Remove the bracing and tack welds or bolts holding the tower tool to the vibrator table.

4.2 Reposition the tool with the parting plane horizontal. The same half must be up to provide access to the lifting lug hole in Detail 203 of the mandrel. Saddle area down.

OPERATION

4.3 Unbolt the two halves and remove the top half of the tool.

4.4 Check for leaks and repair as required (top half).

5.0.0 POSITIONING THE LAY-UP MANDREL ON THE TRUNNION

5.1 Screw the eye bolt into the (-203) large bag end. Attach the lift ring adapter (-212) to the small end of the lay-up mandrel.

5.2 Raise the mandrel from the lower half of the tower mandrel forming tool and place it in the indexing lay-up trunnion stand.

5.3 Check for leaks and repair as required.

6.0.0 LAY-UP OF THE TANK ON THE LAY-UP MANDREL

6.1 Attach with tape the thermocouple wires TC_1 and TC_2 to the mandrel at tank station 83.0 and on the maximum half breadth of the tank. (Ref. HSK-977 drawing). Thermocouple wire ends must be prepared in closed loop by engineering lab to prevent bag puncture.

6.2 Lay up the tank per the engineering specification No. ST0605HA0002 3.1.4.3.1. The engineering drawing will designate the type, direction and number of plys (laminations) of reinforcing fabric. Butt joints are not permitted and laps shall be held to a minimum. When laps are necessary, they shall be held to 3/4 ± 1/4 inch in width and, in successive plys, shall not be superimposed over one another.

Also Note: 3.1.4.3.3 plys shall be added individually and smoothed on the mandrel surface using a squeegee or similar tool. Note this smoothing action is to eliminate wrinkles and pressure should not be such as to remove the resin from the laminate.

6.3 Apply vacuum bag after 7 layers or plys have been layed up and draw vacuum to set the cloth. Do not use heat.

6.4 Remove bag and continue lay-up to completion. Re-apply vacuum bag and draw vacuum to set remaining 7 plys of cloth and saddle ring.

6.5 Use calipers to check final diameter of lay-up to inside of tool HSK 977.

6.6 Transport lay-up under vacuum from supporting dolly HSK 980 to female tool HSK 977. While supporting mandrel and lay-up over female tool HSK 977 remove vacuum bag from lay-up.

6.7 Proceed with instructions in sequence of operations required for Tool HSK 977.

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SEQUENCE OF OPERATIONS REQUIRED
FOR TOOL HSK 977

THE FEMALE FINAL CURE TOOL
LOADING OF TOOL AND
OPERATIONS FOR FINAL CURE
FOR DELIVERABLE FULLY CURED TANK
AND DELIVERABLE FOLDED TANK

SCALE:	~~MATERIAL~~ REVISED [illegible]		
DRAWN:	DATE	NORTH AMERICAN AVIATION, INC. COLUMBUS DIVISION	~~STANDARD~~
[illegible]	DATE 8/30/68		
APPROVED: [illegible]	DATE 8-20-68		

REVISIONS:

FORM H-38-W

OPERATION

1.0.0 PLACING THE LAY-UP AND MANDREL IN THE FEMALE FINAL CURE TOOK HSK-977

1.1 Maintain full vacuum on mandrel while loading. Lift the lay-up and mandrel up out of the lay-up trunnion stand using the lift ring adapter and the eye bolt in the big end of the mandrel that is 90° to the eye bolt hole stamped up. This places the saddle back in a down position for lowering it into the female cavity half of the final cure tool which also has the saddle back area in the lower half.

1.2 Lower the lay-up and mandrel into position over (3 feet) the female final cure tool lower half.

1.3 Remove the tape from the lead in wires on thermocouples (TC_1 & TC_2) that are between the mandrel bag and the set lay-up. Thread the lead in wires through the holes in the saddle back area of the female final cure tool.

1.4 Lower the lay-up and mandrel into place pulling the lead in wires through the holes as the lay-up and mandrel is lowered into place until they are in place. This is to prevent kinking of the lead in thermocouple wires. Add filler blocks between bag and neck and female tool on both ends of mandrel.

1.5 Seal the lead in wire holes on the outside of the female tool with zinc chromate. Fill the seal groove around the half shell area of the female final cure tool with zinc chromate.

1.6 Install the round silicone seal in the seal groove in the top half of the tool and tape into position.

1.7 Lower the top half of the tool until the brass guide pins in the lower half engage.
Make sure that closing the tool does not pinch the sides of the part. Snug all nuts prior to tightening.

1.8 Apply Zinc Chromate to the tool ends to complete the seal with the silicone seal previously installed in 1.6.

1.9 Connect two portable shut off valves and vacuum lines to the upper half of the tool. Repeat for the lower half. Shut off the vacuum from toth ends of the mandrel. While holding five (5) inches of mercury indicating vacuum on the mandrel gage, and the end valves to the mandrel closed draw five (5) inches of mercury on the tool.

1.10 Gradually open the mandrel end valves to release the vacuum in the bag holding the nodules.

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FORM H-86-W

OPERATION

1.11 With five (5) inches of mercury on the female tool vacuum system, and the end valves on the mandrel open, attach the positive pressure air line to the large end of the mandrel and close the valve at the small end. Apply five (5) pounds of positive air pressure to the mandrel.

1.12 Maintain five (5) pounds of positive air pressure to the mandrel. disconnect hoses to vacuum system of female tool and shut valves in four places. Close valve to positive five (5) pounds in mandrel and disconnect hose.

Tool is now free of all connections and may be moved. Mandrel gage should read from 2 to 5 pounds of pressure.

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OPERATION

2.0.0 TRANSPORTING FEMALE TOOL TO ENGINEERING ENVIRONMENTAL CHAMBER

2.1 Movement of tool to the chamber must coincide with negotiated date furnished by engineering.

2.2 Maintain 5 psi. air pressure on bag and lay-up contained in fully assembled female tool.

2.3 Transport tool from Dept. 9 to environmental chamber by lifting with fork lift or on padded truck or steel skid. Do not roll tool on wheels of tool.

2.4 Place tool in chamber in position to hook up thermocouples, air, water, vacuum and electrical circuits.

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FORM M-88-W

OPERATION

3.0.0 CONNECTING FEMALE TOOL TO ENGINEERING ENVIRONMENTAL AUTOCLAVE WATER OR COOLANT

3.1 After positioning tool to be accessible to all required systems, proceed with connections.

3.2 Pipe water from saddle area to environmental connections.

3.2.1 Essentially four water circuits are built into tool having eight 1/2 inch female connections.

3.2.2 Circulation is to be to engineering requirements in autoclave.

3.2.3 Water is required to limit extent of cure zone around saddle land. See Page 13.

3.2.4 Water temperature or rate of flow must be considered variable to maintain cure temperature of 350°F on the part thermocouple 1 inch inside and on net trim edge of part.

3.2.5 Pipe the two side systems into one and pipe each end separately, this will make three (3) individual systems.

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OPERATION

4.0.0 CONNECTING FEMALE TOOL TO ENGINEERING ENVIRONMENTAL CHAMBER ELECTRICAL

4.1 Three strip heaters are located over the saddle land area. Three wires run from the large one piece element and should be wired three phase at the tool junction box to one controller. The other two elements have two wires each and should be wired single phase at the junction box to a second controller.

4.2 Connect one variable control to one circuit and a second control to the second circuit.

4.3 It is anticipated that manual operation of controllers will be required to step the various levels of temperature. After coldest TC is determined automatic equipment may be used.

4.4 The maximum operating temperature of the elements is 500°F.

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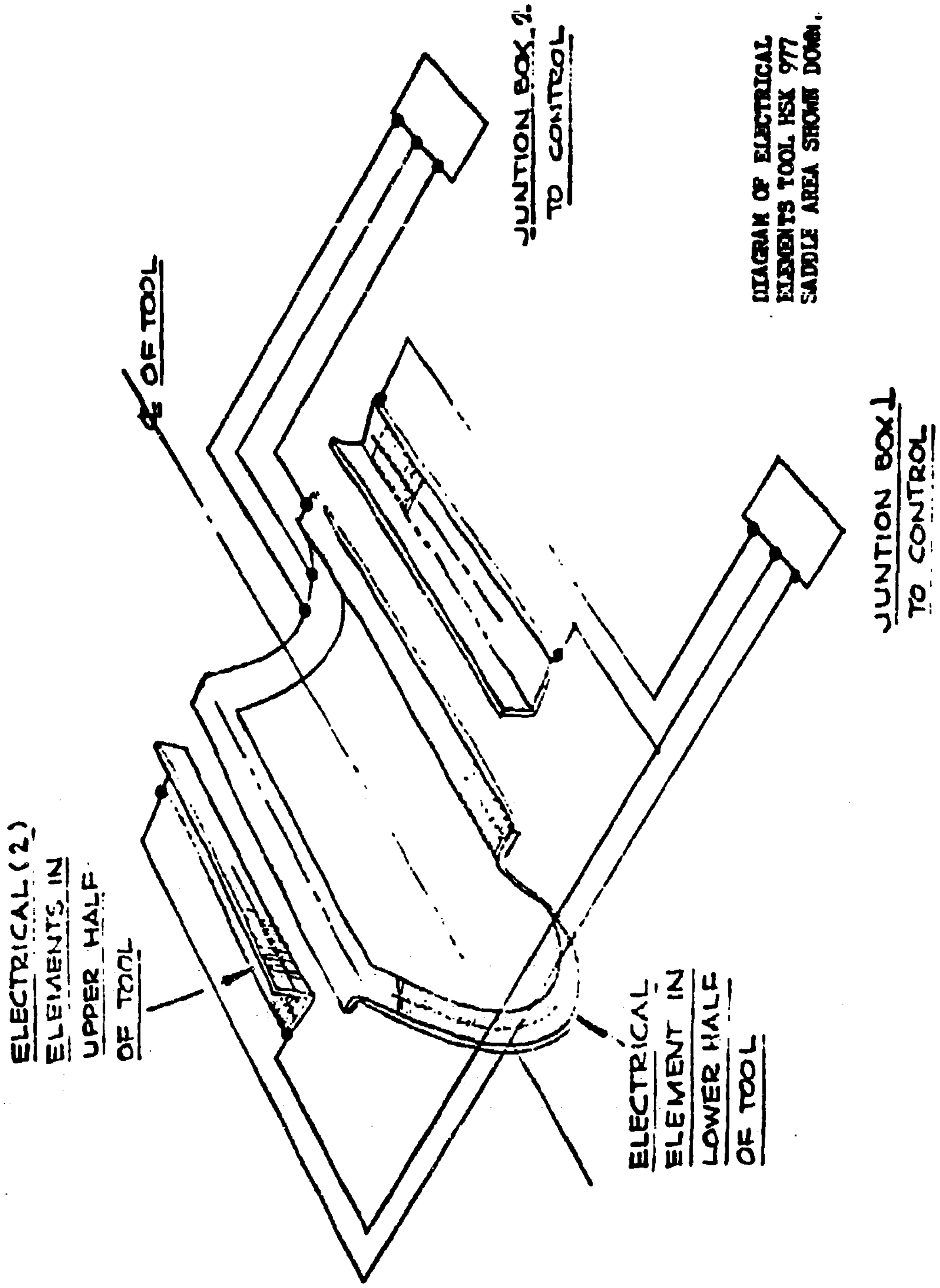
FORM H-86-W



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FORM H-38-W

OPERATION

5.0.0 CONNECTING FEMALE TOOL TO ENGINEERING ENVIRONMENTAL CHAMBER VACUUM

5.1 Connect two (2) 1/2 inch vacuum lines from upper half of tool to two individual lines in chamber.

5.2 Connect two 1/2 inch vacuum lines from lower half of tool to two individual lines in chamber.

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REVISIONS

FORM N-88-W

OPERATION

6.0.0 CONNECTING FEMALE TOOL TO ENGINEERING ENVIRONMENTAL CHAMBER AIR PRESSURE

6.1 With mandrel pressure at 5 psi and end valves closed, connect air hoses to each end of mandrel.

6.2 Open valves but maintain 5 psi on mandrel with chamber system.

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FORM H-36-W

OPERATION

7.0.0 CONNECTING FEMALE TOOL TO ENGINEERING ENVIRONMENTAL CHAMBER THERMOCOUPLE

7.1 Prepare thermocouple chart showing picture of locations from tool drawing, number of thermocouple, time and temperature of position.

7.2 Check thermocouple number and position use only thermocouple numbering system on tool drawing.

7.3 Connect 30 thermocouples to chamber recorder.

7.4 Omit all reading from TC_7, broken wire in tool in build. Also see 3.2.7 water circulation altered to permit reading of TC_7 to be taken at TC_5.

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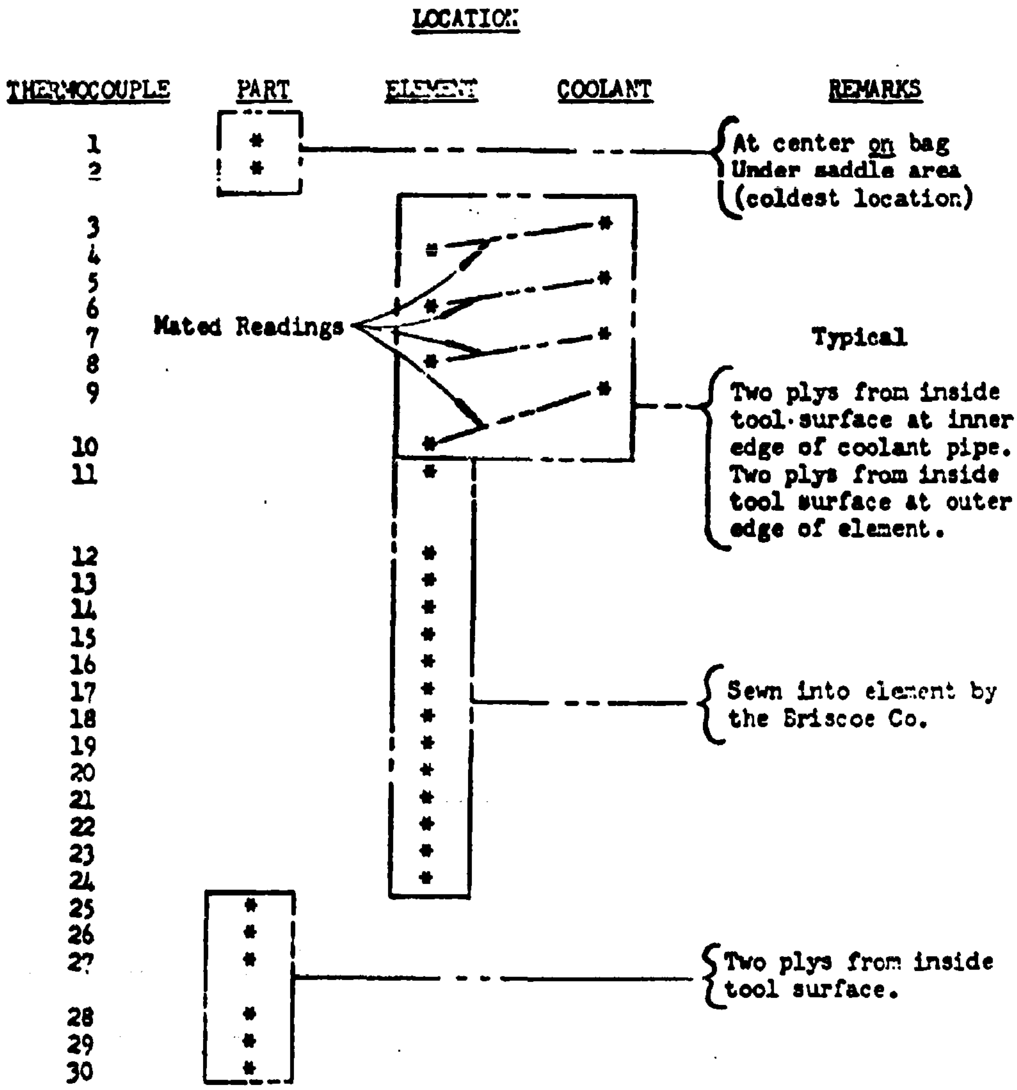
FORM H-20-W



NUMERICAL LISTING OF THERMOCOUPLE POSITIONS AND PERTINENT INFORMATION.

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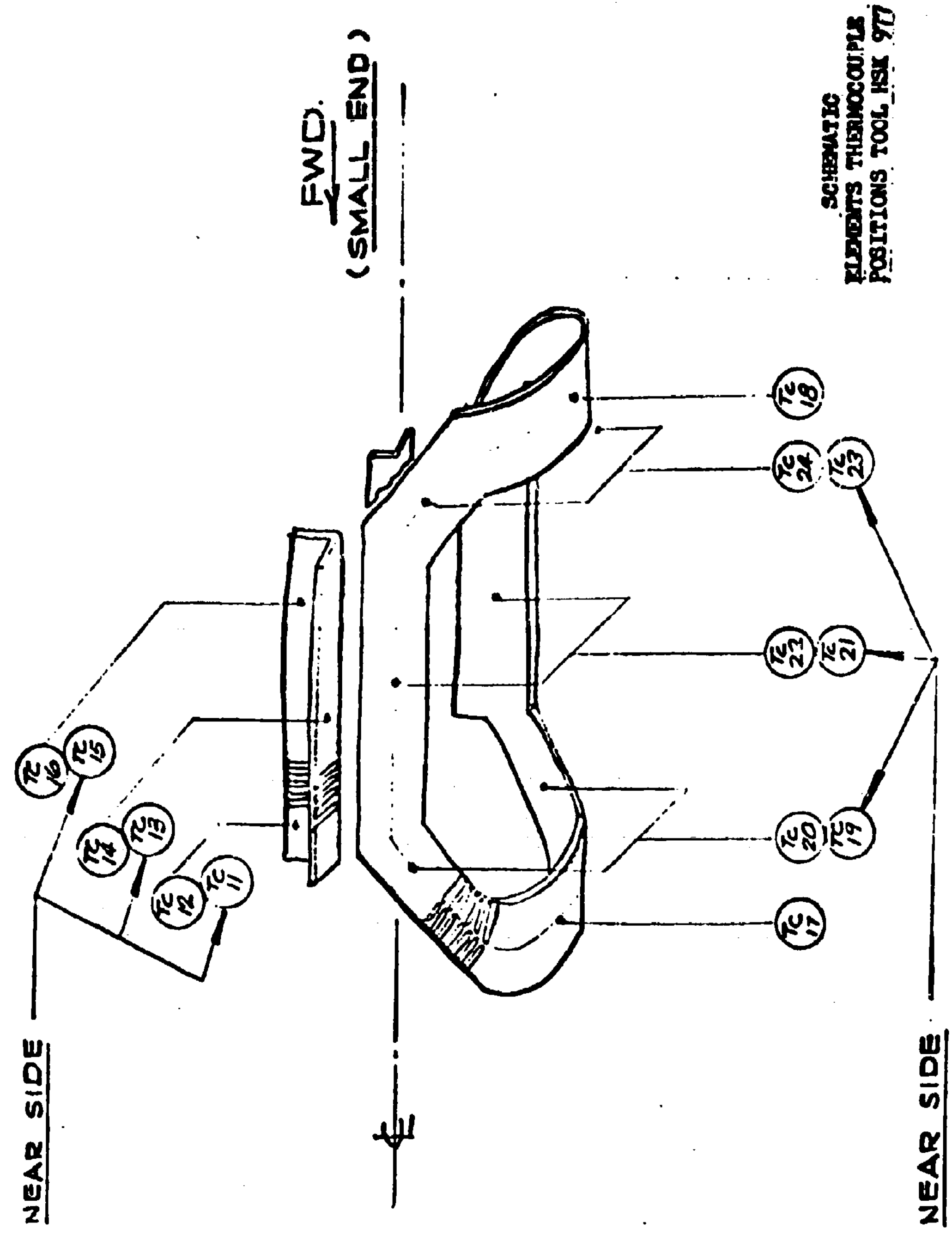
FORM M-38-W



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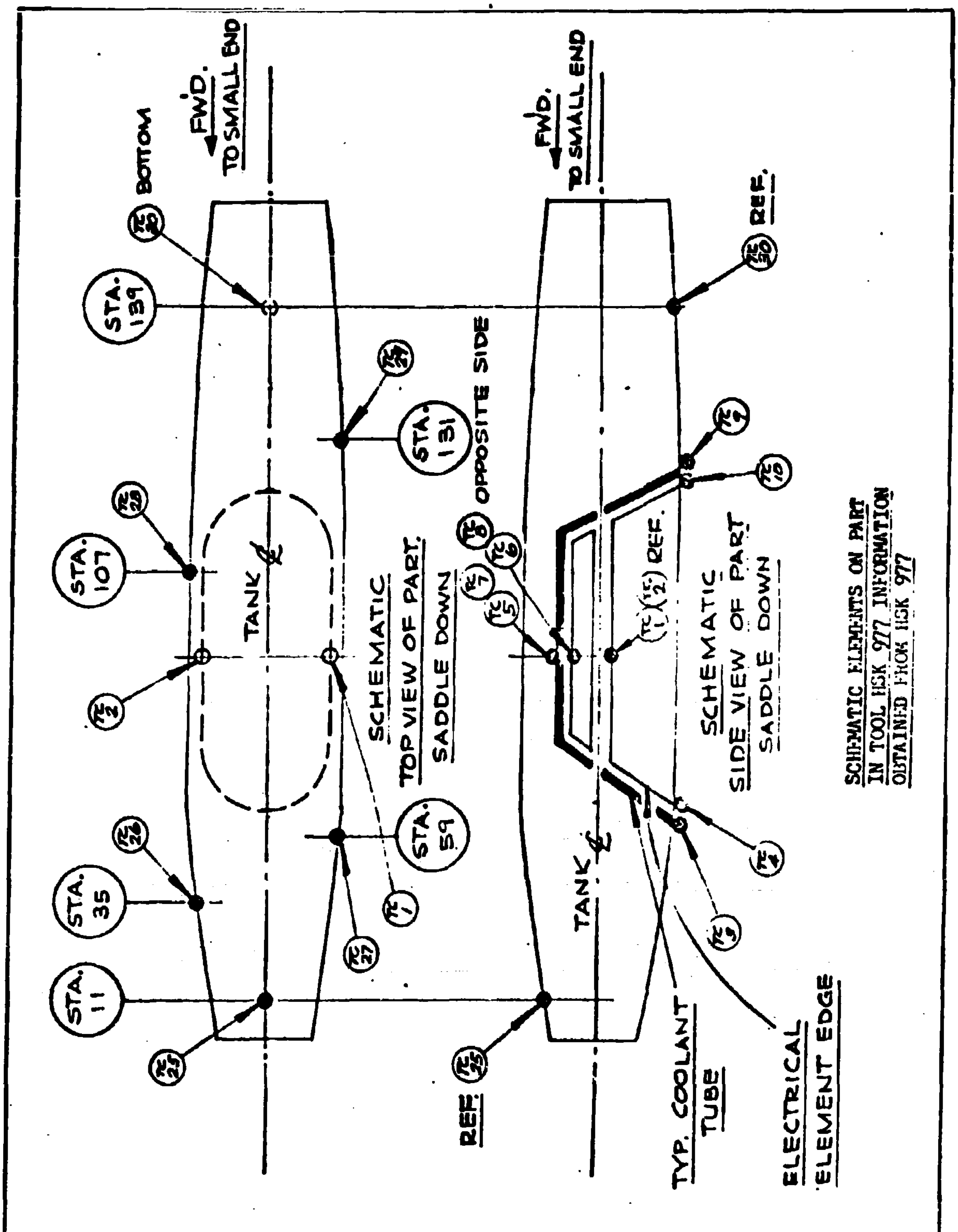
FORM H-38-W



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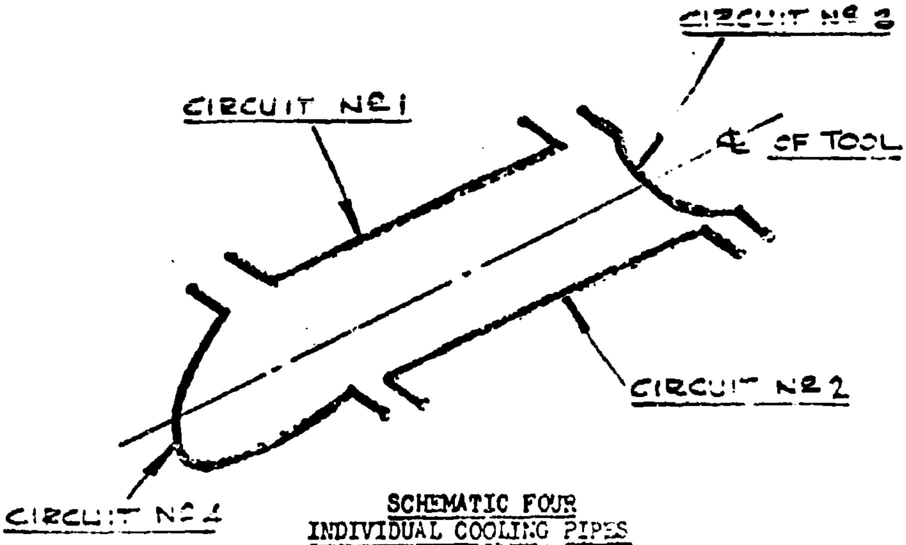
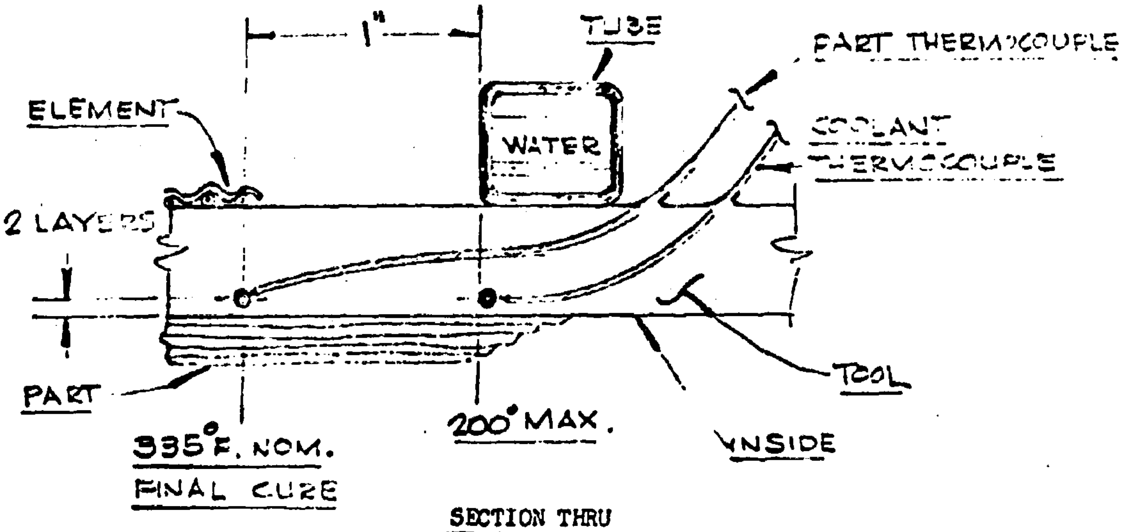
FORM M-30-W



SCHEMATIC FOUR
INDIVIDUAL COOLING PIPES
SADDLE AREA SHOWN DOWN



SECTION THRU
COOLANT PIPE AT
CENTER OF TANK

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FORM N-35-W

OPERATION

8.0.0 OPERATION OF FEMALE TOOL TO PRECURE (170°F) THE TANK AND COMPACT THE LAYERS.

8.1 Layup and mandrel is under five (5) psi. air pressure.

8.2 Chamber heating for this operation is to be used.

8.3 Follow instructions for pre-cure as controlled by engineering specification STO-60-5-HA-0012, 7-2-58 paragraph 3.1.4.4.2.2 and set-up chart in this report in Page 15.

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FORM N-80-W

OPERATION

9.0 OPERATION OF FEMALE TOOL TO CURE SADDLE AREA

9.1 Tool is fully connected to autoclave ready to use pressure bag mandrel and electrical elements in tool.

9.2 Tool is under 5 psi from bag in a start condition. Heat and water cooling is off, thermocouples neutral and full vacuum drawn.

9.3 Safety suggests closing chamber door when pressurizing the tool, to 30 Psi.

9.4 Follow instructions for pre-cure as controlled by engineering specification STO-605-HA-0012, 7-2-68, paragraph 3.1.4.4.2.2 and 3.1.5.2 and included set up chart in this report page 17.

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FORM H-38-W

ENVIRONMENTAL CHAMBER OR AUTOCLAVE HEATING
PRE-CURE IN PREPARATION FOR FOLDING
SCHEDULE OF TOOL OPERATION

ITEM	GENERAL CONDITION	AIR PRESSURE PSI	VACUUM Hg	PART HEAT IN °F	PART HEAT RATE OF INCREASE	TIME PART HEAT DWELL	TIME TOTAL LAPSE
1	Cold	5 Psi	None	70°	None	None	None
2	Change	5 Psi	Buildup	Buildup	Buildup	None	12 Min.
3	Start Compaction or Pre-Cure	Instant 30 Psi	29"	170°F±10°	Maximum Capable Rate of Chamber	Start	7 Hrs. 30 Mins. to bring TC_1 and TC_2 to 170° ± 10°.F.
4	Finish Compaction	30 Psi	29"	170°F±10°	None	27.5±2.5 Minutes	7 Hrs. 57 Mins. start to the Comp. of Compact
5	Cool Down	30 Psi	29	70°	Open Chamber & remove mold	Air Cooled	Natural drop in Temp. to Ambient out of chamber
6	Cold	5 Psi	0	70°	None	None	None

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FORM N-36-W

ELECTRICAL HEATING SADDLE DOOR LAND
AFTER PRE-CURE FOR FOLDING
SCHEDULE OF FEMALE TOOL OPERATION

ITEM	GENERAL CONDITION	AIR PRESSURE PSI	VACUUM Hg INCHES	PART HEAT IN ° F	PART HEAT RATE OF INCREASE	ELEMENT HEAT IN ° F	TIME PART HEAT DWELL	TIME TOTAL LAPSE
1	Cold Start	5 Psi	29"	70°	None	None	None	None
2	Heat Up	5 Psi	29	170°	Element Speed	350°	None	[illegible]
3	Pressure	Instant 30 Psi	29	170°	Element Speed	350°	None	2 Hrs. & 28 Mins.
4	Heat Up	30 Psi	29	Build-up	Element Speed	345° Max. Consider Auto Adj.	None	[illegible]
5	Start of Cure	30 Psi	29	Cold T/C at 325° Hot at 345° Absolute 400°F	Element Speed	345° + Adjust	Start	9 Hrs. & 29 Mins.
6	End of Cure	30 Psi	29	Cold T/C at 325°	None	345° Adjust	3 Hrs.	12 Hrs. & 29 Mins.
7	Cool Down	30 Psi	29	Hot T/C at 190°	None	Off	None	[illegible]
8	Cool Down	0 Psi	0	Hot T/C at 190°	None	Off	May Remove Part	[illegible]
9	Cold	0	0	70°	None	Off	Remove Part	[illegible]

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FORM H-20-W

ENVIRONMENTAL CHAMBER OR AUTOCLAVE HEATING
FINAL CURE ON ENTIRE TANK
SCHEDULE OF TOOL OPERATION

ITEM	GENERAL CONDITION	AIR PRESSURE PSI	VACUUM Hg INCHES	PART HEAT IN °F	PART HEAT RATE OF INCREASE	TIME PART HEAT DWELL	TIME TOTAL LAPSE
1	Cold	5 Psi	29	70°	None	None	None
2	Heat Up	5 Psi	29	Build-up	Autoclave Buildup	None	
3	Pressure	Instant 30 Psi	29	170°	Autoclave Buildup	None	1 Hr. 5 Mins.
4	Start of Cure	30 Psi	29	Cold T/C at 325° Absolute 400°F	None	Start	3 Hrs. 55 Mins.
5	End of Cure	30 Psi	29	Cold T/C at 325° Absolute 400°F	None	3 Hrs.	6 Hrs. 55 Mins
6	Cool Down	30 Psi	29	Hot T/C at 190°	None	Open Oven (1 Hr.10 Mins.	8 Hrs, 5 Min.
7	Cool Down	0 Psi	0	Hot T/C at 190°	Off	Loosen Tool & Remove From Oven	
8	Cold	0 Psi	0	70°	Off	Remove Part	

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FORM M-38-W

OPERATION

10.0.0 REMOVING PARTIALLY CURED TANK FROM TOOL TO DEMONSTRATE FOLDABILITY OF THE MONSANTO MATERIAL.

10.1 After operation 9.0 is completed, fully curing the saddle door land, remove all air, vacuum, water and electrical connections from the tool to the chamber.

10.2 Roll the tool out of the chamber clear floor area under crane provisions in the environmental building.

10.3 Remove all bolts and rods from female tool and lift top half to the floor. Support the tool with wood.

10.4 Cut thermocouples TC_1 and TC_2 off even with outside of tool to avoid feeding wire back through small holes.

10.5 Re-attach lift ring adapter and eyebolt to mandrel ends as in operation 1.4 and prepare to lift mandrel.

10.6 Tighten "C" clamp clevis detail 212 of H3K 976 supporting forward end of mandrel to prevent slipping off of shaft.

10.7 Using special handling beam, lift mandrel out of lower portion of female tool. Thread .040 thick alum. band under saddle area to break part loose from lwr. half of tool if necessary.

10.8 Tilt mandrel lowering aft or large end and rest detail 203 large spherical end on D/64 furnished support.

10.9 Remove detail 204 plug by loosening 205 around 206 then unscrew detail 204. This will open the hole to nodule filler inside bag and allows nodules to drain from bag.

10.10 Catch nodules in suitable container for re-use in second tank to be cured.

10.11 Return mandrel to horizontal position and support in previously used layup trunnion, tool number H3K 980.

10.12 Remove clamps from each end of bag.

10.13 Remove all vacuum and air connections that would prevent removal of trunnion from bag. Mandrel is on stand.

10.14 Screw in 14 foot 3/4" Dia. pipe in forward trunnion end in former vacuum hole.

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OPERATION

10.0.0 (Continued)

10.15 Lift mandrel and part from trunnion stand HSK 98C, and lower into special shop furnished stands supporting mandrel off the floor or a table on diameter of large plug, aft end of part, detail 203, and opposite end is supported on long 3/4" pipe 14' from tank end. Strip the tank and bag off mandrel onto 3/4" pipe.

10.16 While Det. 203, large spherical end, is clamped to trunnion stand, remove bag from mandrel forward (small) end by carefully pulling on neck of bag. Use great care not to rip bag neck.

10.17 As forward end is removed, second operator must push bag off mandrel large end moving bag and part on to length of 3/4" long pipe.

10.18 Indent bag at saddle door land hole which is down and remove thermocouples TC_1 and TC_2 from inside tank between bag.

10.19 Continue removal of part and bag by lifting 3/4" pipe from special trunnion stand. Use third support under steel mandrel end Det. 210 and unscrew 3/4" pipe from 210 while the part is manually supported. Carefully remove 3/4" pipe from bag.

10.20 Monsanto personnel to be present for folding operation.

10.21 Fold per engineering instructions as guided by Monsanto personnel, Attention: Mr. N. Ohanion.

10.22 Tank is to be folded with bag inside and one time only.

10.23 Unfold tank and prepare for drilling.

10.24 Saddle door part has been cured, hole pattern layed out and drilled. This part will be used for a drill plate to transfer the holes into the tank land.

10.25 Position tank in proper working height on low supports.

10.26 Depress flexible portion of tank opposite cured saddle door lands thru hole. Upper part of bag will be depressed to opposite side of part.

10.27 Seal off area in back of cured lands to catch all chips in drilling, and to prevent puncturing bag.

10.28 Route hole opening as required.

OPERATION

10.0.0 (Continued)

10.29 All chips must be removed after drilling because bag will again be used in final cure operation.

10.30 Apply and space edge of drilled saddle door to tank opening.

10.31 Drill all holes using depth stops to prevent drill from puncturing bag.

10.32 Remove saddle door.

10.33 Drill rivet holes around main bolt holes if required per engineering drawing.

10.34 Apply nut plates to back of land using shop furnished stud and wing nut to clamp nuts to saddle land.

10.35 Bond nuts to land.

10.36 Remove protective inner coverings vacuum for chips and clean thoroughly.

10.37 Prepare for final cure.

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OPERATION

11.0.0 RETURNING FOLDED PART TO FEMALE TOOL FOR FINAL CURE

11.1 Tank part has been folded once for either deliverable folded tank #2 or for continued to be cured tank #1. Center steel mandrel has been removed and nodules poured out in either case.

11.2 From the outside toward center of tank, insert shop furnished aluminum shouldered plug, size to conform to detail 210 on HSK 976. Insert plug into bag and reclamp with plug in length position (fore and aft) as shown on HSK 976. Use glass wrap to prevent clamp from cutting bag.

11.3 Repeat 11.2 on large end of tank making plug to conform to detail 203 on HSK 976. Steel center mandrel is not reused due to danger of rupturing bag.

11.4 Shoulders on plugs are necessary to pull the folded tank back into the full length of the female tool. Shoulders of the plugs are pulled over the corresponding shoulders in the female tool.

11.5 Manually lift part and plugs into the female tool and inflate the valve in the large plug to fill out part indentations. This is done with upper part of female tool off. Close shut out valve to keep bag pressure.

11.6 Push and position part into female tool lower half, (as in an inner tube in a tire), paying particular attention to the location of the cured saddle land to the bottom of the saddle land area in the lower half of the female tool.

11.7 Close the upper half of the vemale tool on the lower half and reclamp the vacuum seal through re-application of zinc chromate.

11.8 Clamp one end block in each end of the female tool in front of the bag plugs to prevent plugs from moving outward when bag is inflated. This is not necessary when mandrel 4" center pipe is used because opposing shoulders prevent movement.

11.9 Roll tool back into chamber and re-establish connections to air, vacuum, and thermocouples. Thermocouple numbers TC_1 and TC_2 also TC_{11} through TC_{24} may be omitted since they monitor the element temperatures at the outside surface of the tool. It is not necessary to reconnect the element electrical connections.

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OPERATION

11.0.0 (Continued)

11.10 Follow instructions for full final cure as controlled by engineering specification STO-605-HA-0012, 7-2-68 paragraph 3.1.4.4.2.2 and 3.1.5.3 and included set-up chart in this report, Page 18.

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13. ABSTRACT

A program of work is described leading to the selection of a resin system, reinforcement selection and fabrication methods for building a foldable deployable external wing tank for aircraft. The tank would be fabricated in its final configuration. After fabrication the tank would be folded, stored and shipped to the place of use. At time of use the tank would be unfolded, inflated and cured in its final configuration.

The resin system and glass reinforcement selection was accomplished by screening over 150 potential resin systems and 6 possible reinforcement candidates. Twelve design concepts were screened. The selection of the final design was based on: (1) weight saving potential; (2) high nesting ratio; (3) stiffness and load carrying capability; (4) ease of field erection.

A tooling concept was utilized that would allow the fuel tank to be fabricated over a removable mandrel. The mandrel shape was developed by placing a silicone rubber contoured bag in a female mold with an arbor clamped to the bag. The bag was pressurized against the mold and filled with ceramic (Veri-Lite) nodules. After filling, a vacuum was applied to the bag and nodules to hold the bag in shape when the female mold was removed. After fabricating the tank, the vacuum was released and the nodules removed.

A method for zone curing critical areas of the tank was developed. This allowed the tank to have specific areas cured and drilling and routing operations incorporated at the point of manufacture; and still allowed the final curing of the tank in the field without further machining operations.

The objective of the program was successfully accomplished in that two tanks were fabricated by North American Rockwell. One of the tanks was folded and delivered to the Air Force for future deployment. The second tank was fabricated, folded, deployed and cured at North American Rockwell. This tank was intended for testing for strength and freedom from leaks.

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